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Wind and hail damage to asphalt shingles in Iowa

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WIND AND HAIL DAMAGE TO ASPHALT SHINGLES IN IOWA

by

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Signatures have been redacted for privacy

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The Project

History

"An Investigation of Farm Building Losses Due to Wind and Fire", in 1930 was designated as Project 23 by the Agricultural Experiment Station, Iowa State College. This project is sponsored jointly by the Iowa Mutual Tornado Insurance Association and the Farmers Mutual Reinsurance Association. The project was started when the two associations requested the Iowa Agricultural Experiment Station to conduct a study to determine what types of wind and fire losses are most prevalent in Iowa and what can be done to minimize these losses through improved design of farm buildings, education of farm builders, more frequent inspections, and a more thorough continued maintenance program for the existing farm buildings.

Studies that have been made in the past on this subject are:

1. Statistical Study
2. Aerodynamics
3. Field Observations
4. Structural Analysis

5. Laboratory Tests

6. Design

7. Statistical Study of Types of Building Failures

Statistical studies were made during the period of 1930 to 1933 by Elmer F. Clark (1) and Marvin F. Schweers (5).

The aerodynamic studies have been devoted to using results of other investigators and adapting these results to properly designing a farm structure.

Field observations have been made in the field to determine causes of failures due to windstorm. These have been beneficial to further the improvement of better building practices.

Structural analysis studies of roof shapes have been studied to determine the type roof that will give the greatest stability.

Barn rafters of various types have been constructed to scale and have been submitted to laboratory tests to determine an economical and stable type which can withstand probable Iowa wind storms.

A statistical study of types of building failures was made by Merle L. Esmay (3) for losses occurring in 1946. This study brought to light the fact that asphalt shingles had a much greater chance of damage than did wood shingles.

Purpose

The purpose of this study was to determine what caused asphalt shingles to fail and what could be done to remedy this situation.

The problem

A statistical study of insurance records has been made for 1930-33 and 1946. This study shows that the relative significance of damage to roofing for 1930-33 was much less than that for 1946. This difference is shown in Figure 1. The trend is definitely upward in numbers and amounts of losses for asphalt shingles in comparison to other types of roofs. The usage of asphalt shingles is also trending upwards. The Asphalt Roofing Industry Bureau (7) states that 75 percent of all roofing that was sold in 1937 and 89.6 percent of all roofing that was sold in 1943 was asphalt.

The American Zinc Institute (8) made a survey of roofing in 1941 and 1942. At this time it was shown that 8.0 percent of the total roofing was asphalt shingles. With the consideration that better than 85 percent of all roofing that has been sold since 1943 is asphalt roofing, it can be seen that this percent is increasing in Iowa. Due to these circumstances it is definitely a fact that asphalt shingles are coming into prominent usage in Iowa and that the best method of application is highly desirable.

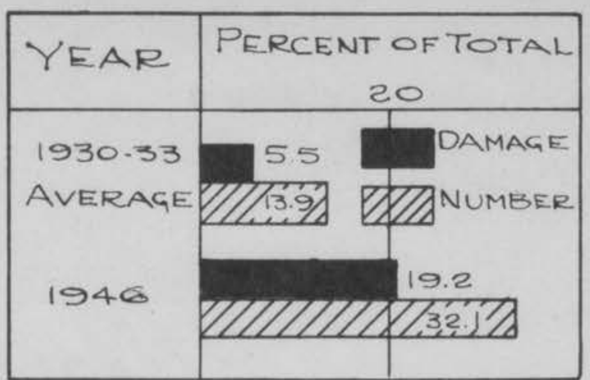

FIG 1. SIGNIFICANCE OF CLAIMS FOR ROOFING DAMAGE

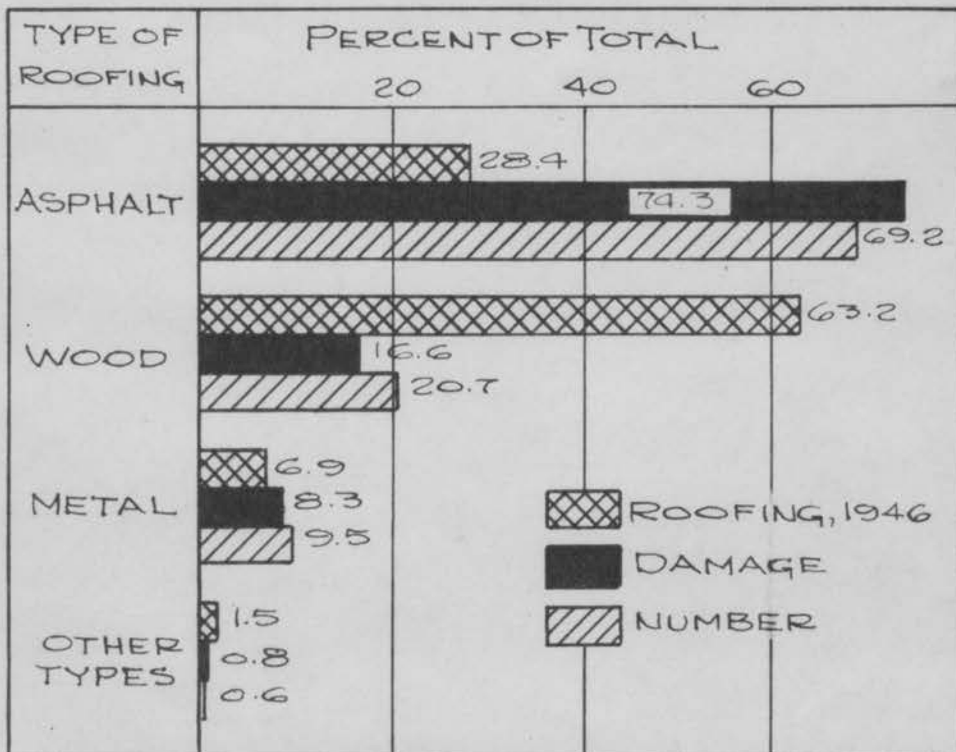

FIG. 2. ROOFING ON FARM BUILDINGS WITH DAMAGE BY TYPE

Justification of the Study

In a thesis by Merle L. Esmay (3) a good deal of pertinent data was compiled as to the probability of damage to asphalt shingles in relation to the damage to wood shingles, and as to the increase in percentage claims between the period of 1930-33 and 1946.

In the 1930-33 period it was shown that roofing damage amounted to 13.3 percent of the claims and 5.4 percent of the structural damage, whereas in 1946 roofing accounted for 33.2 percent of the claims and 20.3 percent of the damage. This is a very marked increase and with the very high percentage of usage of asphalt shingles on the farm it will very evidently increase rapidly upward, if it continues as it has in the past.

A tabulation (3) of the types of roofing on all the buildings involving wind damage claims in 1946 showed that 28.4 percent of them were roofed with asphalt shingles, 63.2 percent with wood shingles, 6.9 percent with metal, and 1.5 percent with all other types. These figures are on numbers of buildings only since no information was available relative to roof areas. However, if we were to assume that the areas for each building were approximately as found in the survey made by the American Zinc Institute (8), the percentage would be approximately as follows: wood shingles 72.8 percent, asphalt shingles 16.07 percent, metal 9.35 percent, and others 1.76 percent. The difference is perhaps primarily due to the fact that asphalt shingles have been used more extensively on the dwellings than on the other buildings and the fact that the dwelling is smaller in roof area than some other buildings, notably the barn.

Figure 2 shows that notwithstanding the fact that asphalt shingles were used on only 28.4 percent of the buildings, it accounted for 74.3 percent of the damage; whereas, wood shingles were used on 63.2 percent of the roofs but accounted for only 16.6 percent of the damage.

On the basis of weighted areas discussed under roofing materials on farm buildings, it would appear that the probability of a claim on asphalt shingles would be 15.4 times (3) as great as the probability of a claim on wood shingles. Also, the probability of amount of loss would be 20.3 times (3) as great for asphalt shingles as for wood shingles. The difference is much more pronounced in the earlier years in the life of a roof. One hundred eighty-four claims were filed on asphalt shingles which were reported to have been laid one year or less. The total claims on roofs five years or less in age were 820 for asphalt shingles and 36 for wood shingles. This is shown graphically in Figure 3.

The main causes for roofing damage are direct wind, hail, flying debris and falling trees. Roofing damage due

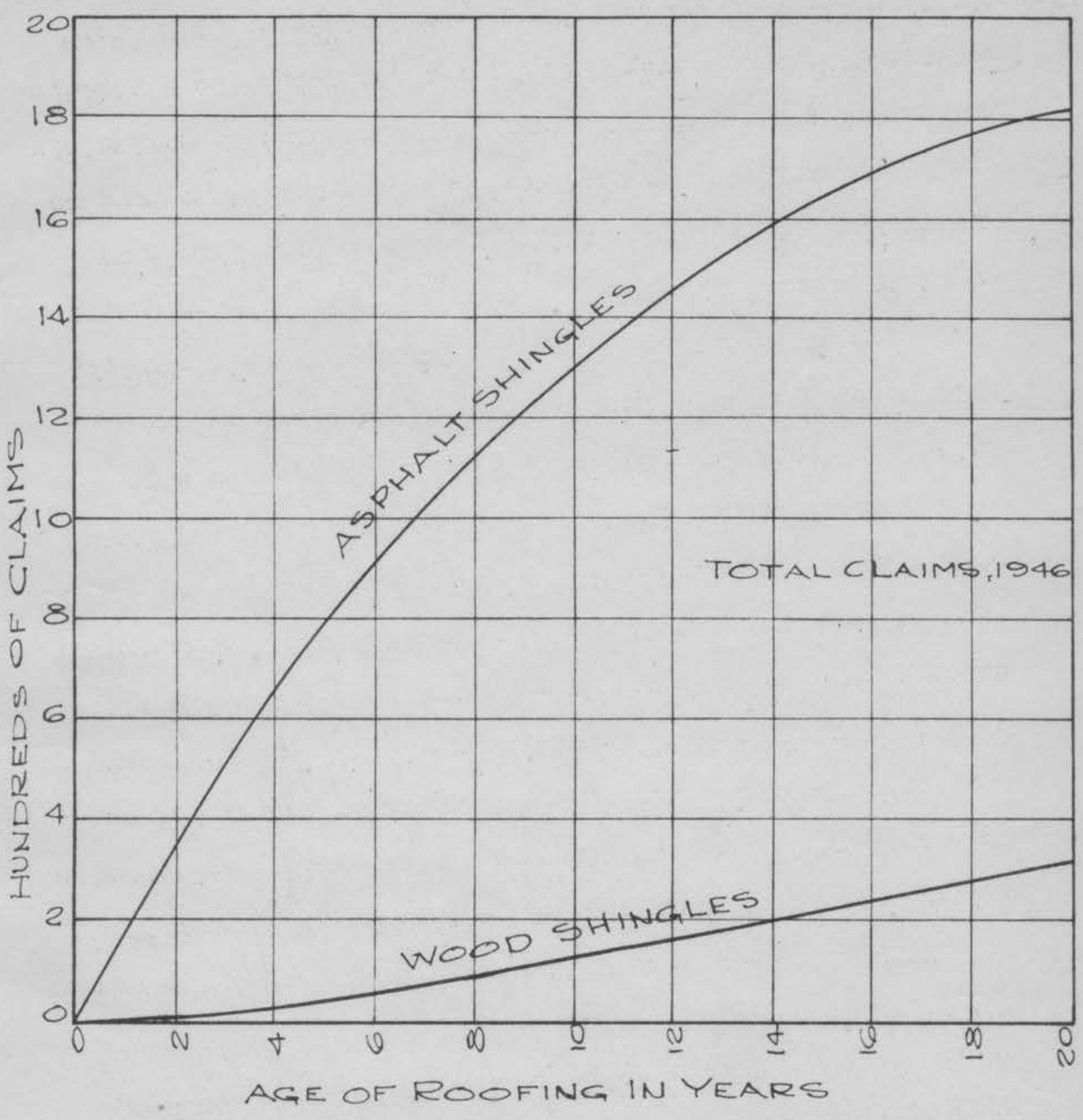

FIG. 3. ROOFING DAMAGE BY AGE OF MATERIAL

directly to wind causes the greatest loss with hail damage second and all others third. Hail damage to asphalt shingles was more than double wind damage, whereas hail damage to wood shingles was nearly equal to wind damage. Figure 4 shows the much larger amount per claim for asphalt shingles than the amount per claim for wood shingles.

The total losses paid in 1946 by the Iowa Mutual Tornado Insurance Association for wind and hail to asphalt shingles was $48,028. It is estimated that this one company insures 90 percent of all farm buildings in Iowa. This would mean that there was approximately $53,360 paid for all farms. The probable damage would have been $220,130 (3) if all the roofs on Iowa farms had been asphalt shingles. When it is taken into consideration that whenever an Iowa farmer receives $1.00 from an insurance company, $2.00 must be paid by the policy holders to the insurance company, the $53,360 amounted to a total cost of $106,720 to the Iowa farmers.

Another consideration must be taken into account as to the total cost of wind and hail to asphalt shingles. This is the saving that could be made if the damaged shingles could be made to last 20 years instead of 7 years. There were a total of 1864 claims in 1946 and each claim had an average area of 11.6 squares (8) which would make a total of 21,600 squares. The average roof was damaged about 10 percent. This would make a total of 2,160 squares to be

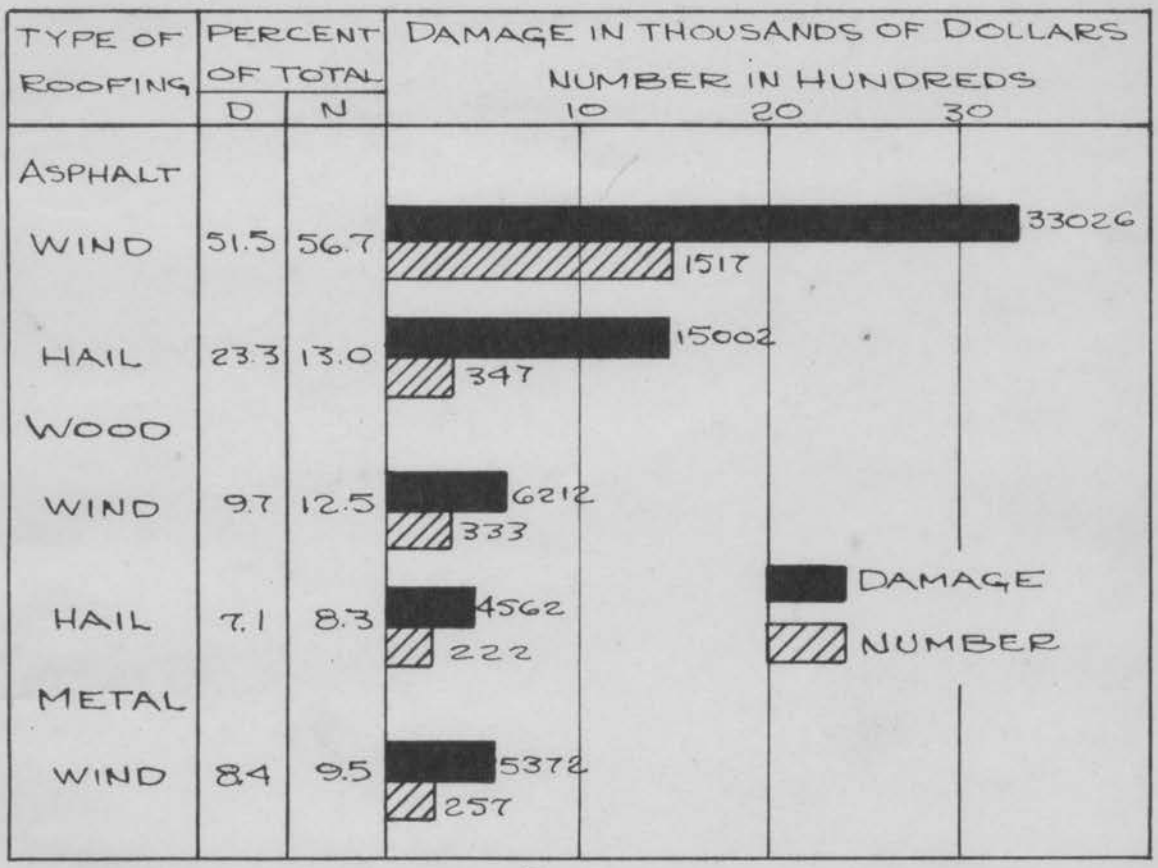

FIG. 4. DAMAGE TO ROOFING BY MATERIAL AND CAUSE

replaced each year. The farmer must pay for 7/20 of the repair cost as this is the basis upon which the insurance company settles. The replacement would total 756 squares at $25.80 per square, which was about the average cost of replacement to the insurance company. The replacement cost of $19,500 plus $53,360 paid by the insurance company plus $53,360 paid in premiums would total a loss of $126,220 for 1946. The saving would amount to but $0.60 per farm in Iowa, but the total saving that could be made is substantial.

The belief at the first consideration of this problem was that the losses were high only on the Iowa farms. Upon a survey made of the losses of the Town Mutual Dwelling Insurance Company, it was shown that this was not true. The Town Mutual Dwelling Insurance Company had approximately 125,000 policies in force in Iowa in 1947. The study covered the period between January 1, 1947 to December 1, 1947. There was a total of 6,524 claims against the company during this period and of these 2,469 were for losses by wind and hail to roofs. Asphalt shingles accounted for 49 percent, roll asphalt roofing for 39 percent, wood shingles for 9.9 percent, and all other, 1.5 percent of the total.

The total number of claims was 1,215 for wind and hail damage to asphalt shingles in comparison to 1,864 on the farms or 65 percent as many claims with this one company as with 90 percent of all farm property in Iowa. There were 701,824 (9) houses in Iowa in 1940. However, farm houses account for about 200,000 of the total which would leave about 500,000 houses in the towns and cities. The Town Mutual Dwelling Insurance Company covered about 25 percent of all the houses in the towns in Iowa. The total claims for Iowa would number about 4,860 for all houses in Iowa. If the average loss for each property in the city was the same as in the country, the total loss would have amounted to \$125,000. The cost to the people in the city would have amounted to \$125,000 plus 7/20 of \$125,000 or \$43,800. This would have made a total of \$293,800 for the people in the towns in Iowa.

The sums of \$293,800 for the city dwellers and \$126,220 for the rural dwellers would make a grand total of \$420,020 of which the insurance companies paid out approximately \$178,360 in losses. The large sum and the rapid rise in probable use of asphalt shingles which would materially increase the losses to be paid, gave impetus to the desirability of a study of wind and hail damage to asphalt shingles in Iowa in order that this cost could be reduced by the better usage of asphalt shingles.

Objectives

The objectives of this study are two-fold: (1) to determine what constitutes a good asphalt shingle roof, and

(2) to determine what constitutes a poor asphalt shingle roof.

A good asphalt shingle roof is considered one that gives the owner of a building 20 or more years of service with no maintenance or repair required. A poor asphalt shingle roof is considered one that conversely does not give 20 years or more service with no maintenance or repair. An asphalt shingle is considered to give good service when it does not blow off or is damaged by hail to either mar the esthetic value of the roof or cause it to leak.

REVIEW OF LITERATURE

The publication of information of a study as to what constitutes a good or poor asphalt shingle roof has not been made as far as the author has been able to find. There has been work done on accelerated tests of asphalt shingles but this is not taken up in the scope of this study. The National Bureau of Standards (6) has done considerable work upon composition and the testing of materials of asphalt shingles. The Bureau has set up standards which must be met if there is any doubt as to the composition of the shingle by the purchaser from the manufacturer. However, this does not give any surety that a good asphalt shingle has been applied, but it does guarantee composition of the shingle as advertised.

The Asphalt Roofing Industry Bureau published a booklet entitled "Manufacture, Selection and Application of Asphalt Roofing Products" in the fall of 1947. This booklet gives a history of the asphalt industry, the materials that go into the makeup of an asphalt shingle, the manufacturing process, the research being done, the various asphalt roofing products, selection for various roofs, application methods, coverage, fire protection, and how to estimate quantities of roofing. This booklet is of considerable help to the people who have obtained it; but this work is inadequate due to the fact that it has not been done with an impartial viewpoint.

History

Asphalt-prepared roofing may be defined as roofing made with a felt base, impregnated with asphalt, and coated with a more viscous asphalt than that used in impregnating felt. Asphalt shingles have been in common use since 1911. The asphalt shingle has been manufactured in various patterns and has been fastened in various ways. There are 145 manufacturing plants of asphalt shingles in the United States.

According to the National Bureau of Standards (6, p.5) "Roofings of the same type, produced by different manufacturers, show but little variation in composition". The reason for this is that the asphalt-prepared roofing industry has established standards of weights for their finished products of the same class. Sources of supply of felt, surfacing granules and mineral fillers are somewhat limited, so that it is not unusual for several producers to obtain these materials from a common source. Another factor that tends to produce uniformity of composition in materials from large and small manufacturers is the inspection service conducted by the Underwriters Laboratories, Inc., in connection with their labeling service.

Asphalt shingles have gained popularity to a great extent due to their fire-resistant property. Good salesmanship and advertising have also been an important factor in their greater use. The esthetic value and economy of asphalt shingles have likewise enhanced their usage.

Asphalt shingles are relatively easy to apply and can be rapidly applied to a roof deck. Usually four nails are used in nailing a strip shingle of the two most common patterns, square butt and hexagonal. There are numerous other patterns which comprise about 10 percent of the total asphalt shingles, and these are fastened in as many ways as there are patterns. In the last three or four years, the Asphalt Roofing Industry Bureau has recommended six nails to a square butt strip shingle and four nails to a hexagonal strip shingle. They have also shown the exact location that nails should be placed on these two most common patterns, square butt and hexagonal, as well as on the individual hex reroofers, staple down, lock down, and individual shingles of the Dutch lap method and the American method.

In the past there have been many differences of opinion among the asphalt shingle manufacturers as to application, exposure and the roof decks. At the present time, under the auspices of the Asphalt Roofing Industry Bureau there seems to be a uniformity of opinion as to a method of application. This booklet also gives the proper method of storage, the best selection for various types of roofs, minimum pitch for different shingles, proper deck construction for new and old decks, proper manner in applying flashings, valleys and ridges and how to compute areas of roofs. This booklet is a step in the right direction but is not believed complete as their recommendations have not proved complete in many instances.

THE INVESTIGATION

With the desire to determine what constitutes a good and a poor asphalt shingle roof, it was first necessary to find what existed on the damaged and good asphalt shingle roofs on the farms in Iowa. The project was set up in the fall of 1947 as "Wind and Hail Losses to Asphalt Shingles in Iowa".

Whenever loss reports were received on asphalt shingles from the Iowa Mutual Tornado Insurance Association, a visit was made to the farms and the roofs were inspected. A questionnaire such as in Figure 5 was filled out. The work in the fall of 1947 went rather slowly as there was much to learn about asphalt shingles by the author. A new questionnaire (Figure 6) was made out for use in the spring of 1948 and due to more losses and a better technique of the author, much more work was accomplished. Losses to the insurance company were relatively light in the spring of 1948 and it was necessary to look for losses in accompaniment with the company's reports. It was attempted to find losses in each county as shown in Figure 7 so that a rather complete understanding of asphalt shingles in the state of Iowa could be obtained.

WIND AND HAIL LOSSES TO ASPHALT SHINGLES

I. Sample Number and Date
   1. Sample number ______
   2. Year, month, day ______

II. Location
   1. Location of farm. County __________ (   )
   2. Protection for bldg. (a) Windbreak ___ (b) Hill ___
      (c) Other bldgs. ___ (d) None ___
   3. Direction of exposure. N ___, S ___, E ___, W _____
   4. Location of damage (a) Ridge ___ (b) Center ___
      (c) Bottom ___ (d) Side ___

III. Building Characteristics
   1. Type of building. (a) Dwelling ___ (b) Barn ___
      (c) Machine shed ___ (d) Hog house ___ (e) Poultry house ___ (f) Crib and Granary ___ (g) Other
   2. Type of roof. (a) Flat ___ (b) Curved ___
   3. Slope of roof, degrees ___

IV. Shingle Characteristics
   1. Type of shingle (a) American ___ (b) Wide space ___
      (c) French ___ (d) Square tab ___ (e) Hexagonal ___
      (f) Other ___
   2. Age of shingle, years ___
   3. Thickness of shingles, inches ___
   4. Inches shingles are exposed to weather ___
   5. Inches of headlap ___
   6. Inches of sidelap ___
   7. Number of plys of coverage, 1___, 2___, 3___, 4___
   8. How the shingle is fastened.
      (a) Galvanized nail ___ (b) Other type nail ___
      (c) Clips ___ (d) Cement ___ (e) Other ___
   9. Number of nails per square ___
   10. Type of deck. (a) Solid sheathing ___ (b) Wood shingles ___ (c) Asphalt shingles ___ (d) Other___
   11. Age of deck, years ___
   12. Per loss in weight of shingles ____
   13. Thickness of felt, inches ___

V. Failure
   1. Were shingles applied as recommended? Yes ___ No___
   2. Cause of failure. (a) Nails pulled through ___
      (b) Nails pulled out ___ (c) Broke ___ (d) Other___
   3. Direction of wind. N ___, S ___, E ___, W ___
   4. Manner wind was blowing. (a) Steady ___ (b) Gusts___
      (c) Other ___
   5. Amount of damage, percent ___
   6. Type of damage. (a) Spots ___ (b) One area ___
   7. Were there previous claims? Yes ___ No ___
   8. Age when previous claims occurred, years ___

VI. Remarks

Figure 5. Questionnaire for Fall of 1947

WIND AND HAIL LOSSES TO ASPHALT SHINGLES

I. Sample Number and Date
   1. Sample Number ____________
   2. Year, month, day ______________

II. Location
   1. Location of farm. County __________________ (   )
   2. Farm operated by (a) Owner ______________ (b) Tenant__________
   3. Name of Owner ____________________________
   4. Protection for bldg. (a) Windbreak__________ (b) Hill__________
   5. (c) Other bldgs.________________ (d) None ________________
   5. Direction of exposure. N______, S_______, E_________, W_______
   6. Direction of wind. N_______, S_________, E_________, W_______
   7. Location of damage (a) Ridge______________ (b) Center__________
      (c) Bottom________________ (d) Side__________________
   8. Who applied shingles? (a) Owner__________, (b) Carpenter_______
      (c) Contractor________________, Other__________________

III. Building characteristics
   1. Type of building. (a) Dwelling_________ (b) Barn____________
      (c) Machine Shed______ (d) Hog house______ (e) Poultry house___
      (f) Crib and granary ____________ (g) Other________________
   2. Type of roof. (a) Flat ______, and (b) Curved________________
   3. Slope of roof, degrees______________________
   4. Was a starter strip used? Yes ___ No ___
   5. Was roofers felt used? Yes ___ No ___

IV. Shingle characteristics
   1. Type of shingle. (a) Square tab ________ (b) Hexagonal ________
      (c) Other____________________
   2. Age of shingle, years _________________
   3. Thickness of shingles, inches ___________
   4. Inches shingles are exposed to weather ______________
   5. Inches nails are from edge of shingle ________________
   6. Number of plys of coverage, 1 ______, 2 ______, 3 ____ 4 ______
   7. How the shingle is fastened. (a) Galvanized nail_______ (b) Other type nail ________ (c) Clips _____ (d) Cement_____ (e) Other_____
   8. Number of nails per square _________________
   9. Type of deck. (a) Solid sheathing ________ (b) Wood shingles_____
      (c) Asphalt shingles ___________ (d) Other __________________
   10. Age of deck, years ____________
   11. Have shingles sealed themselves? Yes ___ No ___
   12. At what angle are nails driven? _______________
   13. Pounds pull to lift shingle _________________
   14. Temperature on roof ____________

V. Failure
   1. Cause of failure. (a) Nails pulled through ______ (b) Nails pulled out ________ (c) Broke ____________ (d) Other____________
   2. Amount of damage, per cent _________________
   3. Type of damage. (a) Spots _____________ (b) One area ___________
   4. Were there previous claims? Yes ___ No ___
   5. Age when previous claims occurred, years _______

VI. Remarks

Figure 6. Questionnaire for Spring of 1948

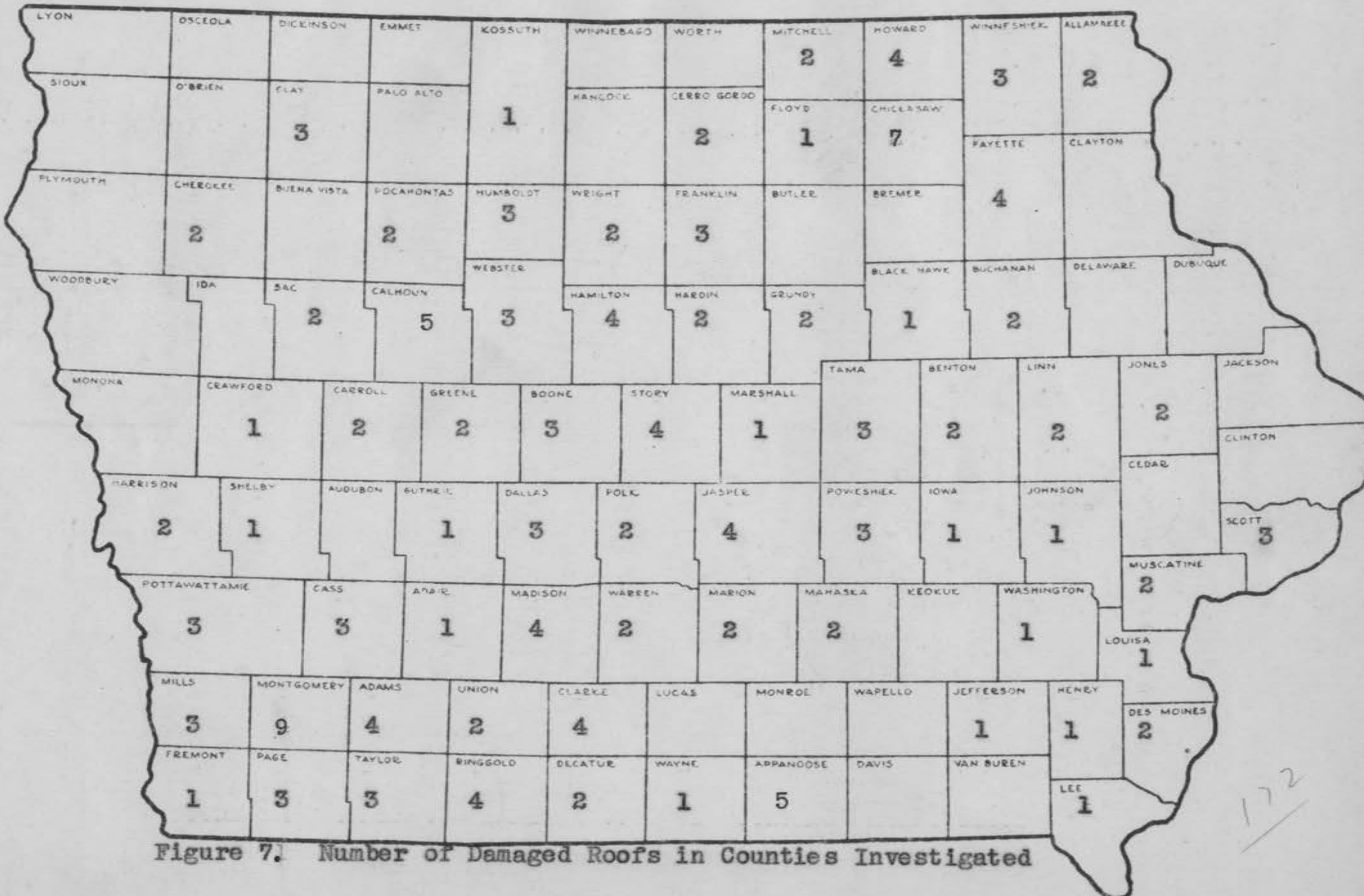

Figure 7. Number of Damaged Roofs in Counties Investigated

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Equipment that was needed for this study included a ladder, county atlas, a contrived apparqtus to determine the slope of roofs, a micrometer, a tape measure, an attachment on a scale to measure pounds pull to lift the tab through 4.25 inches, shown in Figure 15, a thermometer, and a camera.

The questionnaire such as the one on page 19 was made out to obtain any and all information about the asphalt shingle that was available at the site of damage. A space was left for remarks to note the unusual circumstances about the shingle or its application.

In like manner, all data that were pertinent to a good roof were placed on the same questionnaire. Part V of the questionnaire was the only part not applicable to a good shingle roof. Figure 8 shows the counties in which the good asphalt shingles were inspected.

Pictures were taken of many roofs to show various causes of failures and to show how a good roof was applied. Photography is a good deal of help in this type of study as it will show things that are not first seen upon examination at the site of damage.

Lumber dealers and insurance agents were known to have a good deal of influence with the installation and repair of asphalt shingles. Therefore, it was believed helpful to interview these men as to their beliefs and methods of what causes failures, and of how to install a good asphalt shingle roof. At least one man in each county, as shown on the

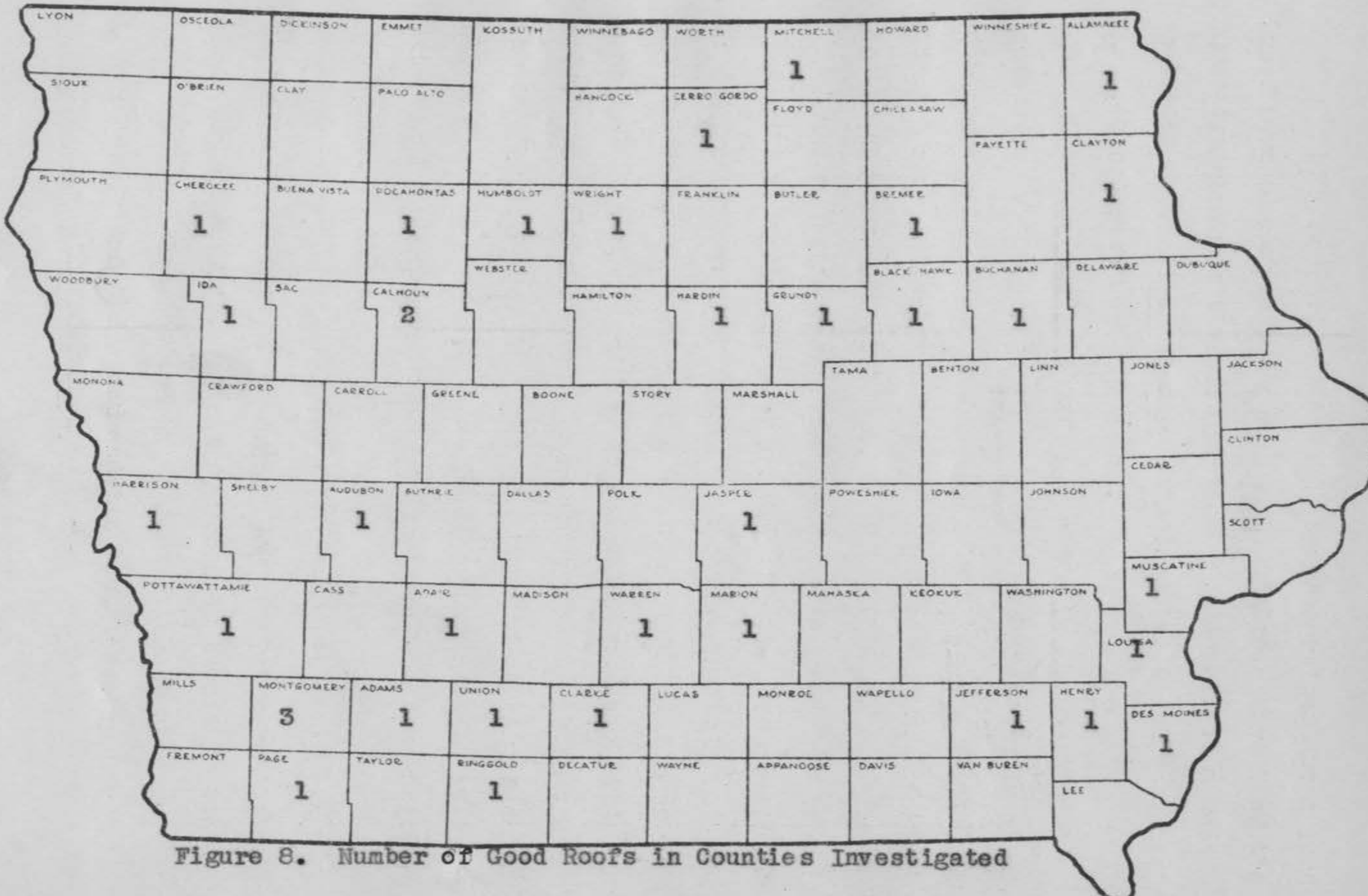


Figure 8. Number of Good Roofs in Counties Investigated

map in Figure 9, was interviewed. A questionnaire such as one on page 25 was filled out by a personal interview. Interviews were secured with men whose businesses ranged from small to large.

Insurance agents and lumber dealers have been beneficial in furthering an understanding of what constitutes good and bad roofing. The study was made to see if there were a correlation between the installation of good and damaged roofs and the recommendations of these lumber dealers and insurance agents.

Laboratory tests were run to determine the physical make-up of an asphalt shingle. This part of the laboratory work was rather sketchy and only points the way for further study. Strips of shingles 1"x4.9" were cut from a die under a hydraulic press. These strips were placed in an asphalt extractor in the Engineering Experiment Station laboratory. The extractor contains an 80-mesh sieve container in which the sample in a filter paper is placed. CS_2 is evaporated at the base of the container and condensed on a water-cooled cone at the top. The CS_2 then drips through the asphalt strip and the bitumen is dissolved. Filter paper is necessary to catch the fine mineral granules as they are too small to be caught on the 80-mesh wire screen. The bitumen is collected in the bottom of the container in solution with the CS_2. The CS_2 evaporates very rapidly and the weight of the bitumen can be weighed after the CS_2 is

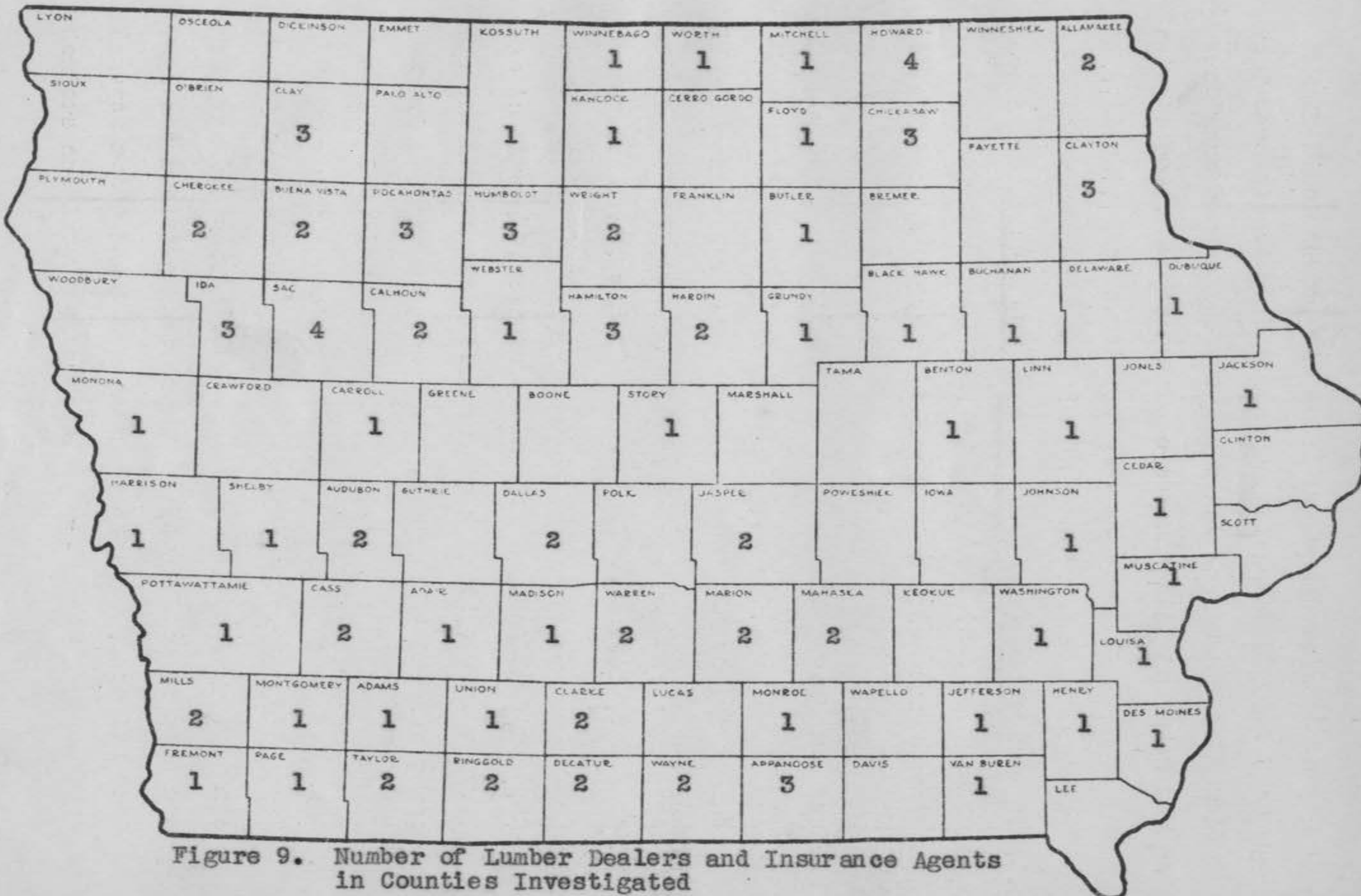


Figure 9. Number of Lumber Dealers and Insurance Agents in Counties Investigated

II Wind and Hail Losses to Asphalt Shingles

1. Name ____

2. Address ______________________________________

3. Dealer's opinion as to cause of asphalt shingle's failure

   ____

4. Is the weight per square a factor? Yes ____ No ____

5. Weight of shingle per square recommended. Less than 210#____, More than 210# ____, 210# ____

6. Number of inches of exposure recommended. 4" ___, 5" ___

7. Number of nails per shingle recommended. 4 ____, 6 ____

8. Is a starter strip recommended? Yes ___ No ___

9. Is a roofer's felt recommended? Yes ___ No ___

10. Is the angle at which nails are driven a factor? Yes ___ No ___

11. Have you used clips? Yes ___ No ___

12. Do you recommend clips? Yes ___ No ___

13. Have you used cement? Yes ___ No ___

14. Do you recommend cement? Yes ___ No ___

15. At the time of application, is weather a factor? Yes ___ No ___

16. Have you used a lock-corner shingle? Yes ___ No ___

17. Do you recommend a lock-corner shingle? Yes___ No___

18. Do shingles seal themselves? Yes ___ No ___

Figure 10. Questionnaire for Lumber Dealers and Insurance Agents

evaporated. The large colored granules can be separated from the fine granules by sieving.

These tests were but a preliminary survey and could not be considered very accurate. The felt must be completely free from bitumen. This was difficult to determine. There was no investigation of the material from which the felt was composed. The study of the physical make-up of an asphalt shingle would entail a large size study in itself.

More laboratory work was done on the amount of pounds pull required to pull a 7/16" nail head through different asphalt shingles at various temperatures, as shown in Figure 11. The data taken on page 28 show the amount of pull required to pull a nail head through a 2 tab hexagonal, a 3 tab hexagonal and a 3 tab square butt asphalt shingle at 50° F., 88° F., 132° F. and 150° F. Nails were also pulled through an asphalt shingle at a 60° angle to the shingle. The average pound pull required to pull the nail head through was 12 pounds.

The pound pull required to lift an asphalt shingle tab through 4.25 inches was also taken. These data and the number of times the tab could be bent at the edge of exposure of a 2 tab hexagonal, a 3 tab hexagonal, a 3 tab square butt with 4" exposure and a 3 tab square butt with 5" exposure are shown on page 30 and in Figures 12 and 13.

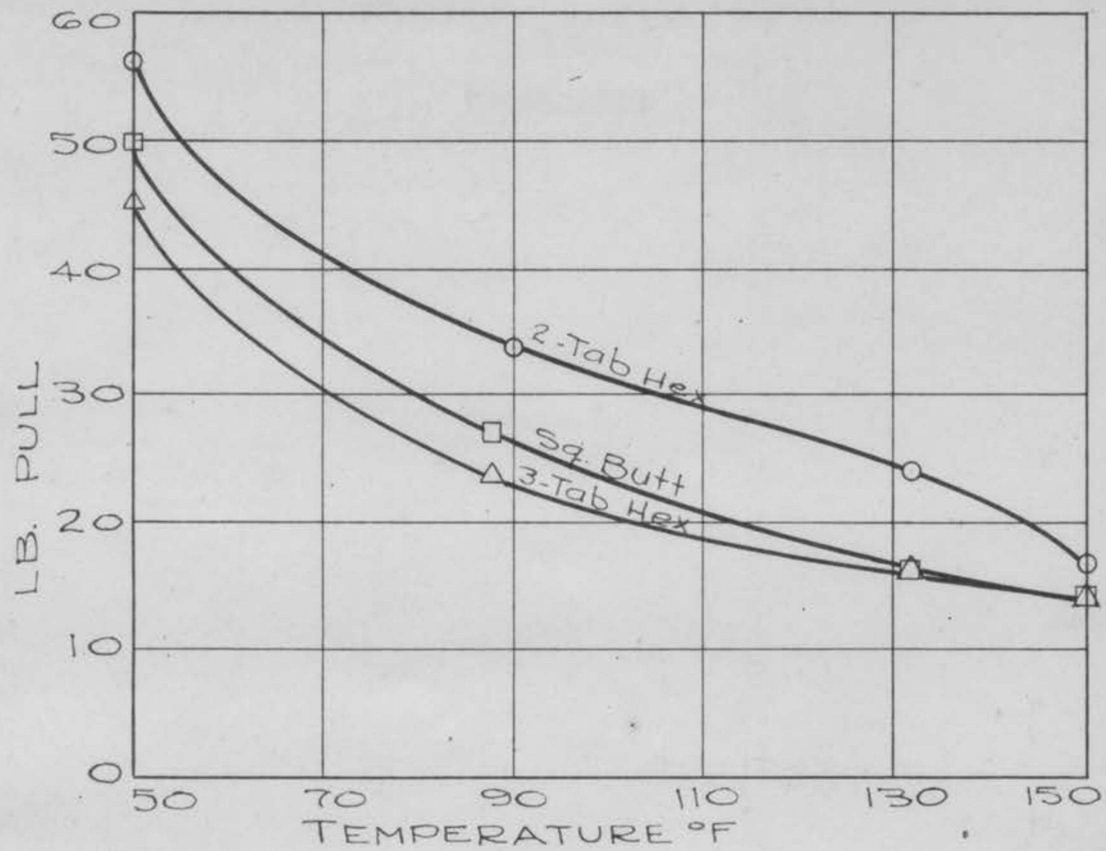


FIG. 11. 7/16" NAIL HEAD WITHDRAWAL RESISTANCE

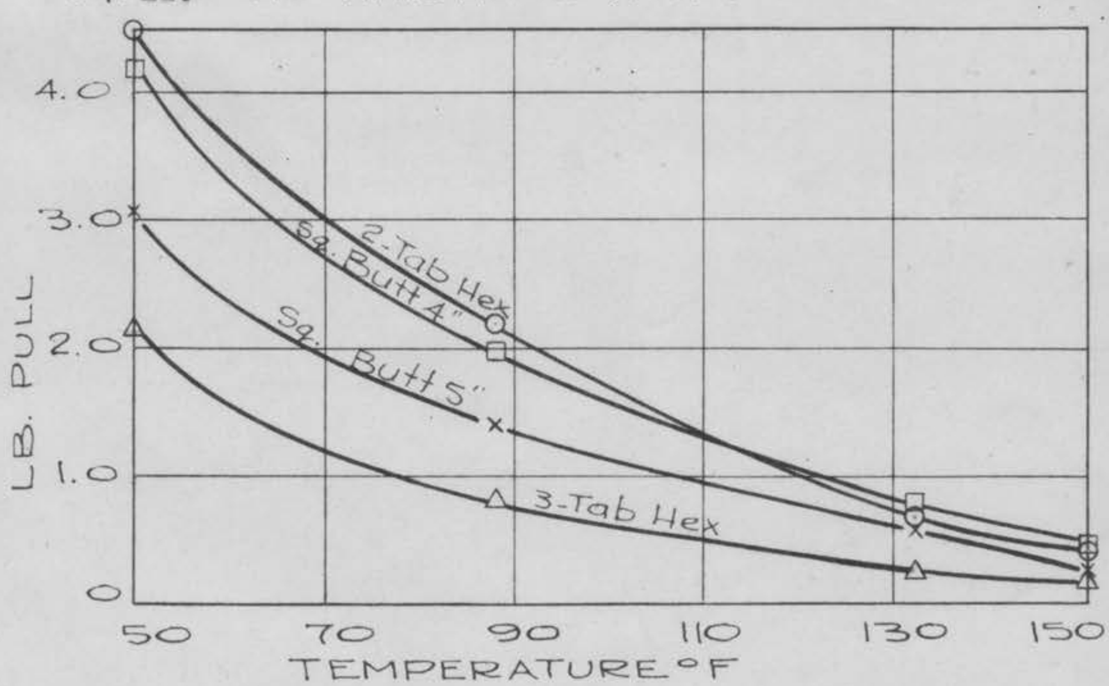


FIG. 12. PULL TO LIFT TAB 4.25 INCHES

Table I. Force to Pull Nail Head Through Shingles

Name	Cleveland, R.	Thickness - As stated		Head size - 7/16" D.	
Project	23	Brand name -		Date - 7-7-48	
Leader	Giese, H.	Type asphalt shingle - As stated		Area - 24 in.^{2}	

Asphalt shingle	Trial	Nail-withdrawal resistance Temperature 50 °F.	88 °F.	150 °F.	132 °F	Remarks
3 Tab	1	48	24	15	18	Post-war. All shingles nailed
Hex	2	44	23	14	16	as specified in Bulletin put out
Lb. pull	3	45	24	14	16	Asphalt Roofing Industry Bureau.
Thick. 0.137	4	43	25	13	15	Copyright 1947. Title: Manu-
	5	44	24	14	15	facture, Selection and Applica-
	Av.	45	24	14	16	tion of Asphalt Roofing Products
Square butt	1	51	27	17	15	
Lb. pull	2	51	26	14	15	
Thick. 0.171	3	51	27	14	17	Post-war
	4	49	25	13	15	
	5		27	13	17	
	6		27			
	7		27			
	Av.	50	27	14	16	
2 Tab	1	56				
Hex	2	54	32	18	23	
Lb. Pull	3	55	34	18	23	Pre-war
Thick. 0.148	4	56	34	17	25	
	5	57	34	17	24	
	Av.	56	34	17	24	

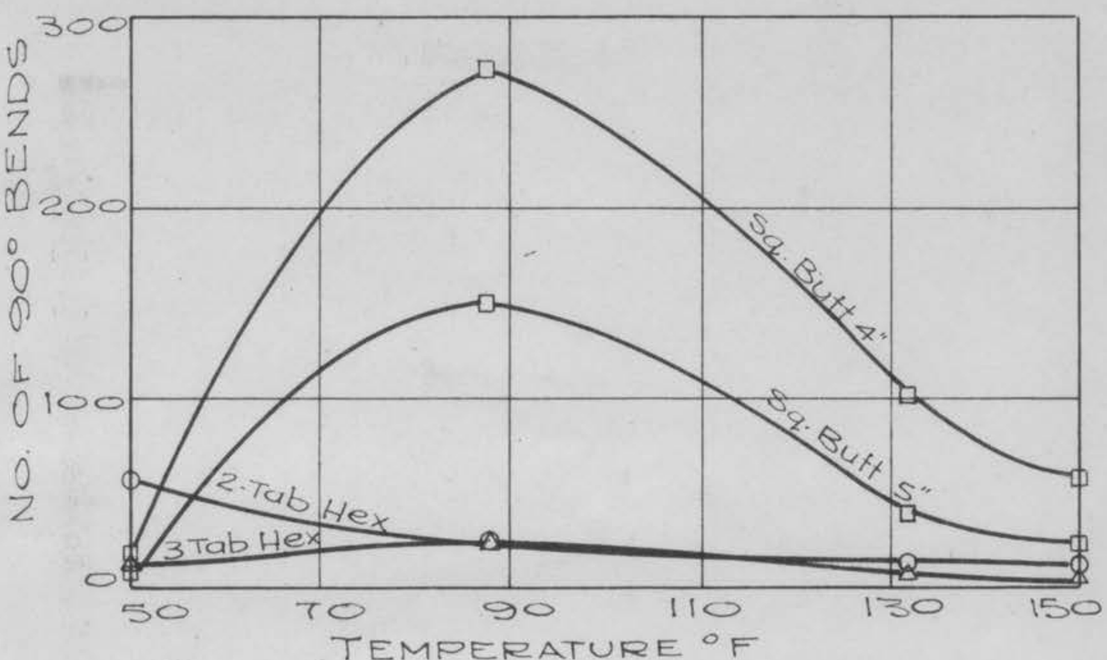


FIG. 13. NO. BENDS THROUGH 90°

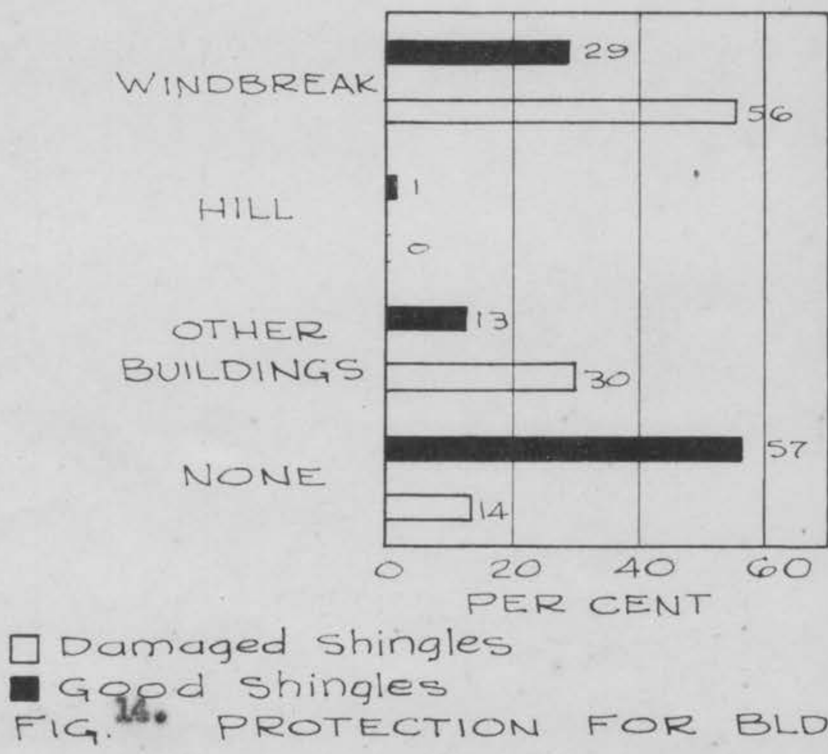


FIG. 14. PROTECTION FOR BLDG.

Table II. Number of Bends Through 90°, Pounds Pull To Lift Tabs and Computed Wind Velocity To Lift Tabs

Name Cleveland, R.
Project 23
Leader Giese, H.

Distance pulled - 4.25"
Date - 7-7-48
Distance bent - 90°

Wind velocity to cause tabs to lift -

Asphalt shingle	Trial	50 Lb. pull	50 No. bends	50 Wind vel.	88 Lb. pull	88 No. bends	88 Wind vel.	132 Lb. pull	132 No. bends	132 Wind vel.	150 Lb. pull	150 No. bends	150 Wind vel.
3 Tab	1	2.12	14		0.80	25		0.20	9		0.16	8	
Hex	2	1.84	15		0.72	30		0.24	9		0.14	7	
Thick. 0.137	3	1.76	8		0.70	24		0.20	9		0.15	7	
	4	1.80	7		0.72	23		0.16	9		0.16	7	
	5	1.54	8		0.68	20		0.20	9		0.15	7	
	Av.	1.68	11	46	0.72	25	26	0.20	9	14.3	0.15	7	12.3
2 Tab	1	3.94	50		2.15	27		0.52	11		0.36	9	
Hex	2	3.96	70		1.60	30		0.56	12		0.40	9	
Thick. -.148	3	4.16	45		2.20	23		0.76	10		0.38	10	
	4	4.80	62		2.44	24		0.56	10		0.32	8	
	5	5.68	54		2.64	22		0.84	10		0.36	9	
	Av.	4.51	56	67	2.20	25	48	0.60	11	25.8	0.36	9	19.0
3 Tab	1	2.72	10		1.24	150		0.56	40		0.24	30	
Square butt	2	3.08	11		1.28	148		0.58	42		0.23	25	
5" exposure	3	3.04	10		1.32	154		0.56	40		0.24	24	
Thick. 0.171	4	3.12	8		1.24	147		0.48	36		0.23	27	
	5	3.24	9		1.40			0.56			0.20	25	
	Av.	3.04	10	24.5	1.38	150	15.4	0.55	39	10.4	0.23	26	6.7
3 Tab	1	4.20	11		1.66	265		0.80	90		0.36	60	
Square butt	2	4.24	9		2.16	270		0.79	90		0.40	62	
4" exposure	3	4.08	11		1.84	280		0.76	92		0.32	58	
Thick. 0.171	4	4.12	10		2.16	278		0.78			0.44	55	
	5	4.20	9		1.96			0.74			0.40		
	Av.	4.17	10	28.5	1.96	273	19.5	0.77	91	12.2	0.38	59	8.7

Temperatures (50, 88, 132, 150) are in °F.

Red cedar wood shingles (No. 1 grade) with a 4", 4.5" and 5" exposure and various widths were lifted at the butts and broken at the edge of exposure as shown in Figure 17. These data are shown on page 33 and Figure 19. Asbestos cement shingles were also lifted at their butts and broken over the edge of exposure as shown in Figure 18. These data are shown on page 33 and in Figure 19.

Fig. 15. Method Tab Was Lifted 4.25 Inches

Fig. 16. Weathering Due to Different Slopes

Fig. 17. Method Red Cedar Wood Shingles Were Broken

Fig. 18. Method Asbestos Cement Shingles Were Broken

Table III. Force To Break Wood and Asbestos Cement Shingles

Name Cleveland, R.
Project 23
Leader Giese, H.

Distance pulled until broken
Date - 7-6-48
Temperature - 92°F.

Material	Trial	Bending Force - Pounds Pull					
		Exposure - Inches					
		4.0		4.5		5.0	
		Lb. pull	Width	Lb. pull	Width	Lb. pull	Width
No. 1 Red	1	88	2.625	82	3.125	76	3.75
Cedar Wood	2	116	2.812	78	3.125	52	4.0
Thickness	3	84	2.50	86	3.812	60	3.125
4.0 0.315	4	68	2.25	90	3.812	74	4.0
4.5 0.307 5.0 0.294	Av.	89	2.55	84	3.47	66	3.72
	#/in.	34.9		24.2		17.75	
Asbestos	1	58					
cement	2	36					
Thick. 0.172	3	52					
Width 30"	4	30					
Exposure 5.5"	5	54					
	6	46					
	Av.	46					
	#/in	1.5					

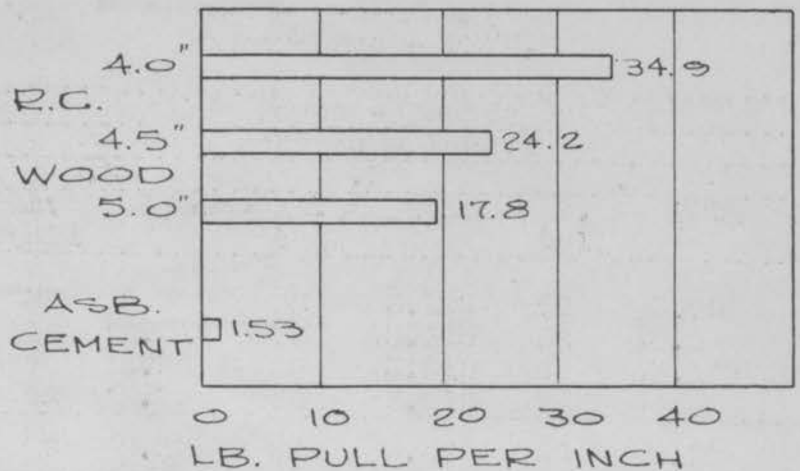


FIG. **19.** FORCE TO BREAK

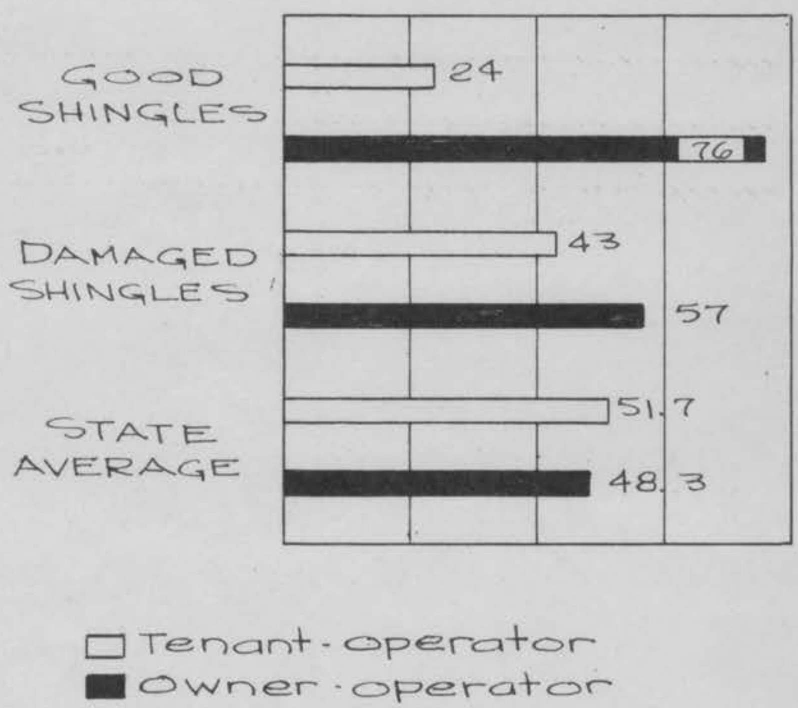


FIG. **20.** FARM OPERATED BY

RESULTS AND FINDINGS

Field Study

Good roofs

Good roofs as defined before are those roofs that have given 20 years or more service with no damage occurring to them. The total number of good roofs investigated were 36. These roofs were located as shown in Figure 8. There were a number of significant factors brought out in the data collected on these roofs. These data are shown by number in Table IV and by percentages in Table V.

Locations. The percentage of owner-operator farms on which good shingles were found was predominantly high in ratio to the state average of owner-operator farms. This is shown graphically in Figure 20. The percentage of owner-operator farms with good roofs amounted to 76 percent. This can be explained by two probable reasons: (1) Whenever a home is built to be used many years as a family home and there is a pride of possession and family ties, the best shingle that can be purchased is generally used and, also, the best known manner of application is practiced. (2) Unless the home had been owned by one family for this 20-year period, it was not generally possible to find the age

Table IV. Questionnaire of Good Shingles by Number

WIND AND HAIL LOSSES TO ASPHALT SHINGLES

I. Sample Number and Date
 1. Sample number______________
 2. Year, month, day__________________

II. Location
 1. Location of farm. County____________________ (   )
 2. Farm operated by (a) Owner __25__ (b) Tenant __8__
 3. Name of Owner____________________
 4. Protection for bldg. (a) Windbreak __19__ (b) Hill __0__
  (c) Other bldgs. __10__ (d) None __5__
 5. Direction of exposure. N______, S______, E______, W______
 6. Direction of wind. N_____, S_____, E_____, W_____
 7. Location of damage. (a) Ridge_____ (b) Center______________
  (c) Bottom_________ (d) Side__________
 8. Who applied shingles? (a) Owner __2__, (b) Carpenter __25__,
  (c) Contractor __0__, Other __0__

III. Building characteristics
 1. Type of building (a) Dwelling __28__ (b) Barn __13__ (c) Machine shed __0__ (d) Hog house __0__ (e) Poultry house __1__
  (f) Crib and granary __0__, (g) Other __0__
 2. Type of roof. (a) Flat __33__ and (b) Curved __0__
 3. Slope of roof, degrees __34__
 4. Was a starter strip used? Yes __2__ No __29__
 5. Was roofers felt used? Yes __3__ No __25__

IV. Shingle characteristics
 1. Type of shingle (a) Square tab __13__ (b) Hexagonal __6__
  (c) Other __14__
 2. Age of shingle, years __22__
 3. Thickness of shingles, inches __0.174__
 4. Inches shingles are exposed to weather __4.36__
 5. Inches nails are from edge of shingle __5.33__
 6. Number of plys of coverage, 1 __4__, 2 __7__, 3 __20__, 4______
 7. How the shingle is fastened. (a) Galvanized nail __33__
  (b) Other type nail __0__ (c) Clips __0__ (d) Cement __0__ (e) Other __0__
 8. Number of nails per square __552__
 9. Type of deck. (a) Solid sheathing __22__ (b) Wood shingles __7__
  (c) Asphalt shingles __0__ (d) Other __0__
 10. Age of deck, years __28__
 11. Have shingles sealed themselves? Yes __13__ No __16__
 12. At what angle are nails driven? __90__
 13. Pounds pull to lift shingle __2.36__
 14. Temperature on roof __71, 97__

V. Failure
 1. Cause of failure. (a) Nails pulled through ______ (b) Nails pulled out________ (c) Broke ________ (d) Other____________
 2. Amount of damage, percent__________
 3. Type of damage (a) Spots______________ (b) One area __________
 4. Were there previous claims? Yes____ No____
 5. Age when previous claims occurred, years __________

VI. Remarks

Table V. Questionnaire of Good Shingles by Percent

WIND AND HAIL LOSSES TO ASPHALT SHINGLES

I. Sample Number and Date
   1. Sample number__________
   2. Year, month, day__________
II. Location
   1. Location of farm. County__________ ( )
   2. Farm operated by (a) Owner 76 (b) Tenant 24
   3. Name of Owner__________
   4. Protection for bldg. (a) Windbreak 56 (b) Hill 0
      (c) Other bldgs. 30 (d) None 14
   5. Direction of exposure. N____, S____, E____, W____
   6. Direction of wind. N____, S____, E____, W____
   7. Location of damage (a) Ridge____ (b) Center____ (c) Bottom____
      (d) Side____
   8. Who applied shingles? (a) Owner 7 (b) Carpenter 93
      (c) Contractor 0 , Other 0
III. Building characteristics
   1. Type of building (a) Dwelling 96 (b) Barn 0 (c) Machine
      shed 0 (d) Hog house 0 (e) Poultry house 4
      (f) Crib and granary 0 (g) Other 0
   2. Type of roof. (a) Flat 100 and (b) Curved 0
   3. Slope of roof, degrees 34
   4. Was a starter strip used? Yes 6 No 94
   5. Was roofers felt used? Yes 10 No 90
IV. Shingle characteristics
   1. Type of shingle (a) Square tab 40 (b) Hexagonal 18
      (c) Other 42
   2. Age of shingle, years 22
   3. Thickness of shingles, inches 0.174
   4. Inches shingles are exposed to weather 4.36
   5. Inches nails are from edge of shingle 5.33
   6. Number of plys of coverage, 1 13 , 2 22 , 3 65 , 4 0
   7. How the shingle is fastened. (a) Galvanized nail 100
      (b) Other type nail____ (c) Clips____ (d) Cement____
      (e) Other____
   8. Number of nails per square 552
   9. Type of deck. (a) Solid sheathing 76 (b) Wood shingles 24
      (c) Asphalt shingles 0 (d) Other 0
   10. Age of deck, years 28
   11. Have shingles sealed themselves? Yes 45 No 55
   12. At what angle are nails driven? 90
   13. Pounds pull to lift shingle 2.36
   14. Temperature on roof 71, 97
V. Failure
   1. Cause of failure. (a) Nails pulled through____ (b) Nails pulled
      out____ (c) Broke____ (d) Other____
   2. Amount of damage, per cent____
   3. Type of damage (a) Spots____ (b) One area____
   4. Were there previous claims? Yes____ No____
   5. Age when previous claims occurred, years____
VI. Remarks

of a roof except in the case of insurance records and, therefore, it was necessary to pass some roofs by with no investigation.

The predominance of owner-operator farms was undoubtedly not good statistically. However, the main objective was to obtain data on good asphalt shingles. The owner-operator was the only type available from whom data could be collected. There was no thought in mind at any time to collect data on a state-wide average of operator-owner farms as these farms were found by inquiry of insurance agents, lumber dealers, neighbors and mostly by chance. The data collected are believed to be a representative sample of good asphalt shingle roofs. There was not a plentiful number of them and in most instances it was difficult to find a roof of this type in the country. However, there did seem to be quite a number in the towns and cities.

Trees were of great value to an asphalt shingle roof. In 56 percent of the roofs examined, windbreaks were found. Windbreaks seemed to cause air movement to go over the building. Trees that were close to the building which gave shade to the shingles were also of much value. An asphalt shingle that is protected from the sun by either direction of slope or the shade of a tree will last considerably longer and be in much better condition than one that is directly exposed to the sun. This can be shown by the evidence of Figure 21 in comparison to Figure 22. In like manner, other buildings were of benefit in protecting the asphalt shingle roofs. Protection for buildings is shown graphically in Figure 14. Windbreaks and other buildings were found in 86 percent of the cases investigated, whereas in 14 percent of the cases there was no protection for good asphalt shingle roofs.

The carpenters of Iowa applied 93 percent of the good roofs while the owners applied the other 7 percent. It was not determined what the experience or ability of the carpenters were. There were no roofs applied by contractors. The Table IV on page 36 shows who applied the shingles.

Building characteristics. As could be expected, the dwelling had 96 percent of the good shingles. This is the most expensive structure on the farm and the one in which the most pride is generally taken. Also, the desire for protection from fire is greatest on the house. Fire resistant qualities of asphalt shingles have had more to do with the installation of an asphalt shingle than any other factor. The esthetic value of the asphalt shingle is also a large contributing factor and has been desired by the owner to dress up his home. In turn, other buildings on the farm have had asphalt shingles installed to keep roof harmony on all the buildings.

Fig. 21. North Slope of a 28 Year Old Roof

Fig. 22. South Slope of a 28 Year Old Roof

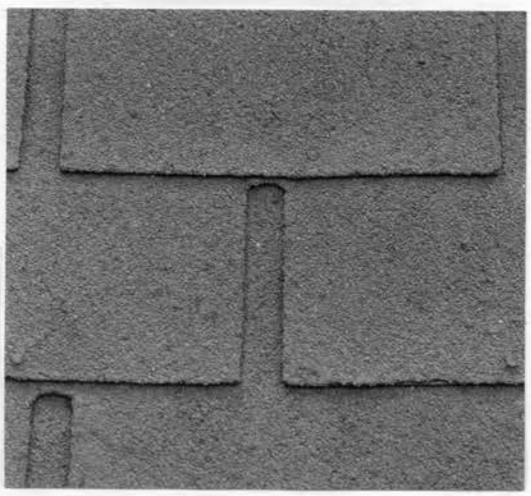


Fig. 23. Nail Driven Through Tab

Fig. 24. Irregular Weathering

All good asphalt shingles were found on flat roofs with none being found on curved roofs of the round or gothic pattern. The reason for this is that the curved roofs have come into more prominent use in the last few years. This study in no way shows that an asphalt shingle could not last as long on this type roof as on a flat type roof such as a gable, hip or gambrel roof.

The average slope of a good roof was 34°. The extremes were from a minimum of 20° to a maximum of 60°. The roofs with the least slope weather the faster due to the action of the sun. There were but two roofs with less than 30° slope and these were both heavily shaded by trees. The steeper sloped roofs will give longer service if the sun is the only factor in causing a roof to wear. Figure 16 will show evidence of this fact.

A starter strip or an eaves flashing strip is defined by the Asphalt Roofing Industry Bureau as a mineral surfaced roll roofing of a color to match the shingles which should extend up the roof far enough to cover a point at least six inches inside the inside wall line and should extend from one end of a roof to the other end. This was found in but 6 percent of the good asphalt shingles inspected. In 94 percent of the cases there was no starter strip used. However, in all roofs examined it was the practice to reverse the shingle in lieu of a starter strip. The Asphalt

Roofing Industry Bureau recommends the use of both a starter strip and an asphalt shingle reversed.

Roofers felt was applied only 10 percent of the time on good asphalt shingle roofs, whereas 90 percent of the time it was not applied. The use of a 15 lb. roofers felt has not been employed to any great extent but is being employed more widely in the last few years.

Shingle characteristics. In noting the type of shingles being used in Iowa, it was found that on 2141 roofs in 55 counties the two most common patterns, square butt and hexagonal, were on 90 percent of the asphalt shingle roofs. The first number denotes a square butt; the second number, a hexagonal; and the third number, all others. This is shown in Figure 25. All other patterns made up the other 10 percent. The inspection of good asphalt shingle roofs showed that the square butt accounted for 40 percent, the hexagonal for 18 percent, and others for 42 percent of the roofs examined. The percentages do not have the proper correlation but one factor that could not be observed from the road was whether a shingle was a square butt, which were on 65 percent of all roofs noted, or whether it was an individual shingle, as is listed in the other group of 10 percent of all roofs. Thirteen out of fourteen of the other group pattern were individual shingles with the fourteenth one being a tee-lock shingle.

Total roofs observed. No.-Hex, 530; Square butt, 1382; Others, 229. W-wood; S-steel;
% " 25 " " , 65 " , 10. RR-Roll roofing;

1st no., Square butt;
2nd no., Hex.;
3rd no., Other

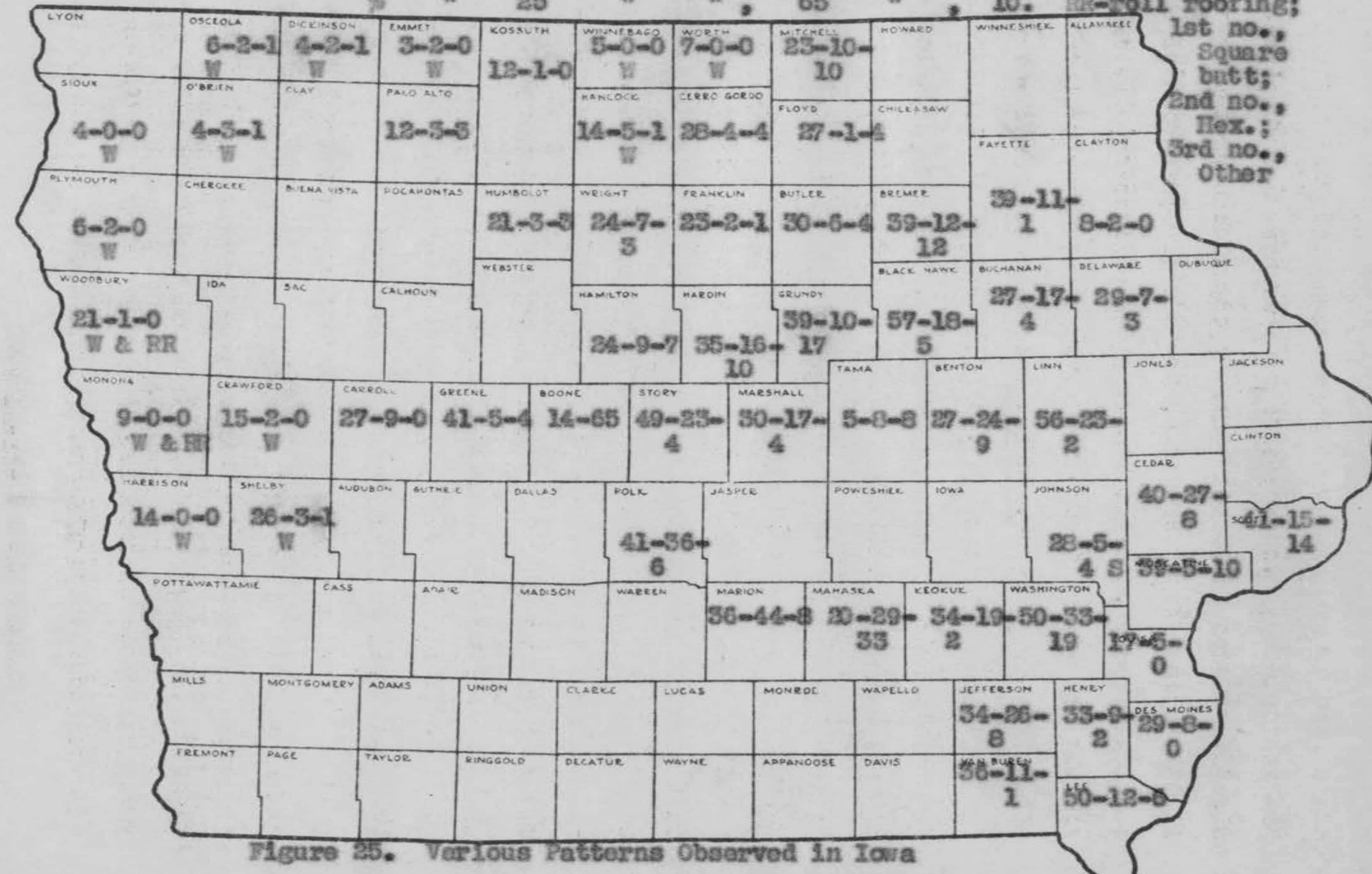


Figure 25. Various Patterns Observed in Iowa

The individual patterned shingle as shown in Figure 21 has seemed to have done a very excellent job of giving long service, although it is not being manufactured today. This type of shingle is generally 8 inches by 13 inches. They were thicker than the average shingle used today and had about twice as many nails per square as the more common patterns used today.

The average age of the good asphalt shingle was 22 years with the oldest shingle found being 30 years old. Most of the shingles examined were in fairly good condition and should give from 5 to 10 more years service with no trouble.

Asphalt shingles varied in thickness from 0.120 inches to 0.250 inches with the average thickness of 0.174 inches as shown in Figure 27. Shingles wear out and decrease in thickness through the years. Some shingles wear out uniformly as shown in Figure 28, whereas other shingles do not and come off in small sections as shown in Figure 24. The average thickness of the good shingles after 22 years service is 0.022 inch greater than the average new shingles now commonly sold.

Exposure of a shingle is defined as the "distance between exposed edges of adjacent courses measured at right angles to the eaves" by the Asphalt Roofing Industry Bureau booklet. The average exposure of a good asphalt

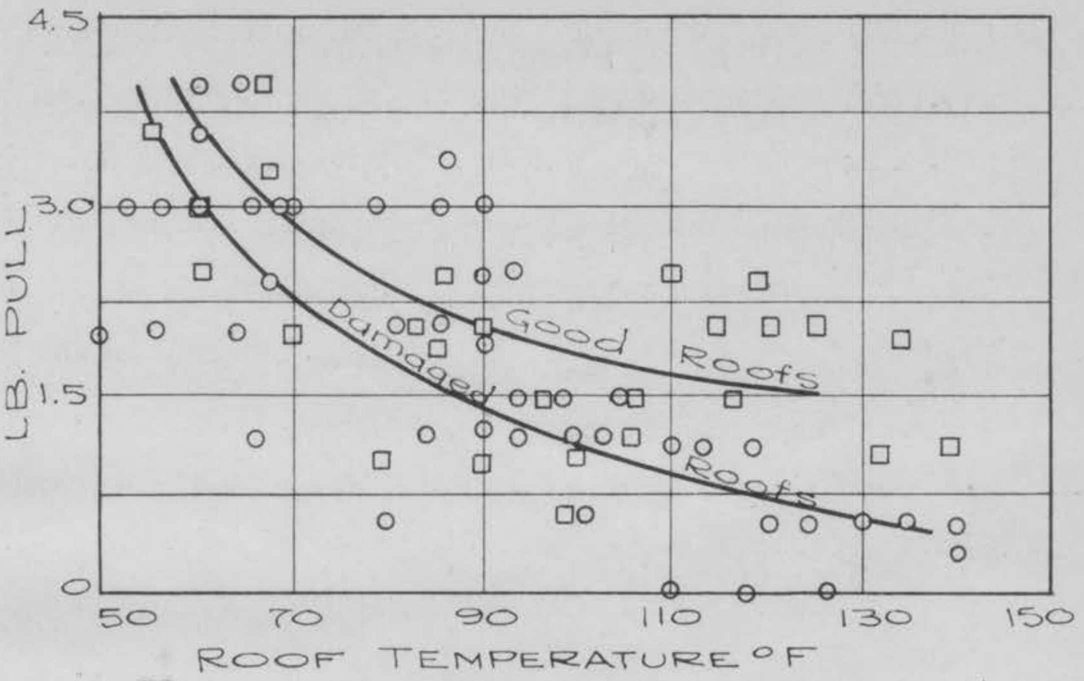


FIG. 26. LB. PULL TO LIFT TAB 4.25"

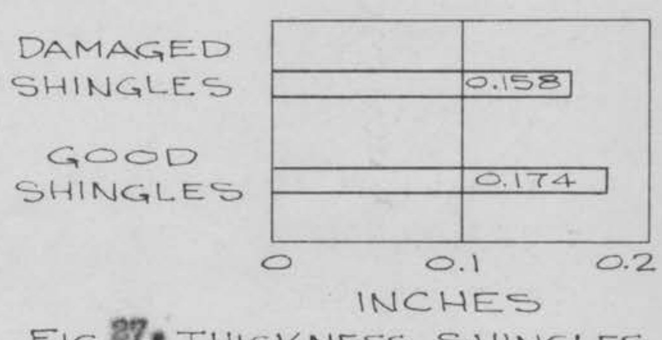


FIG. 27. THICKNESS SHINGLES

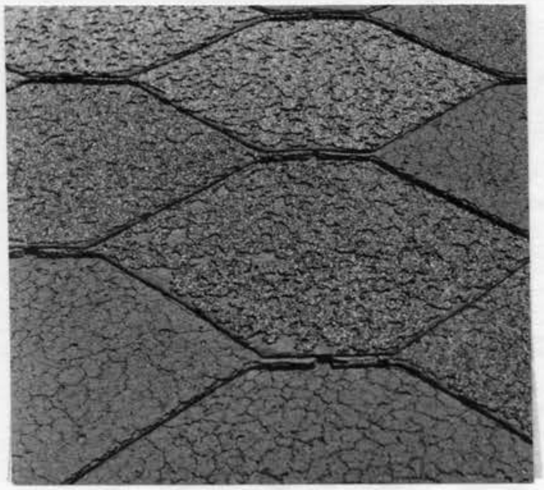


Fig. 28. Even Weathering

Fig. 29. Ten-Year Old Chipped Shingle

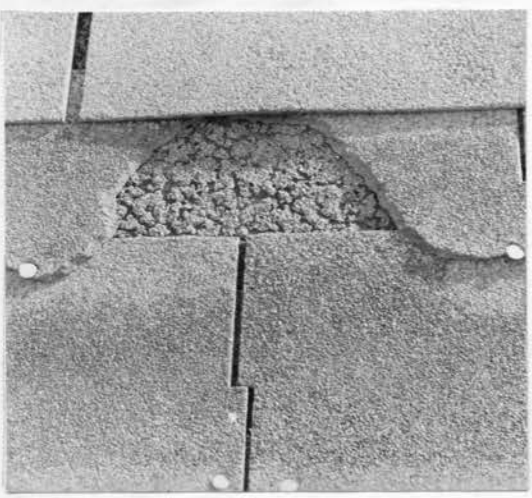


Fig. 30. Nailed at an Improper Angle

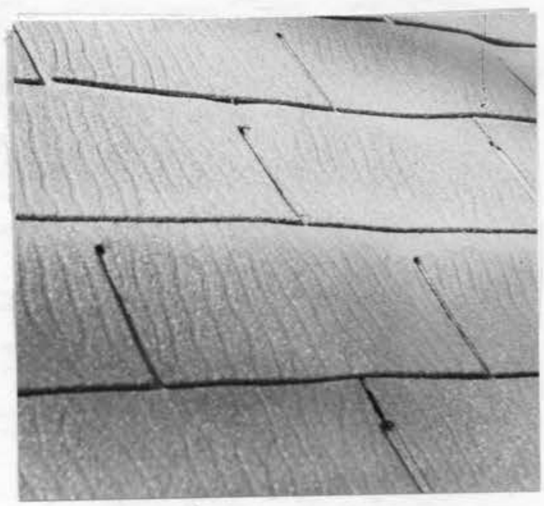


Fig. 31. Too Much Exposure

shingle roof was 4.36 inches as shown by Figure 33 and Table IV. The exposure varied from 3 inches to 5 inches for the good shingles. The exposure as an average was less than is now being used on an average new installation. Figure 31 shows an example of improper exposure.

The distance that a nail was placed from the edge of the shingle averaged 5.33 inches or approximately one inch more than the amount of exposure. This distance was 3/8 of an inch more than recommended by the Asphalt Roofing Industry Bureau. However, it was about as close as could generally be maintained by carpenters. This distance from the edge of the shingle was a large contributing factor to the life expectancy of an asphalt shingle. Invariably the good shingles were carefully nailed as to this distance and the lever arm of the exposed surface was kept at a minimum.

Sixty-five per cent of the good asphalt shingles had a three ply coverage while 22 per cent had two ply coverage and 13 per cent had one ply coverage as shown in Figure 34. The amount of coverage was a contributing factor to the water proofness of a roof if any tabs were broken, but was not a contributing factor to the roof's lasting 22 years. This can be explained by the fact that whenever a roof wears out, it is only the surface exposed that is worn out. If a tab does not blow off, a single coverage shingle with the same thickness and material would last as long as a triple coverage shingle. However, the triple coverage shingles

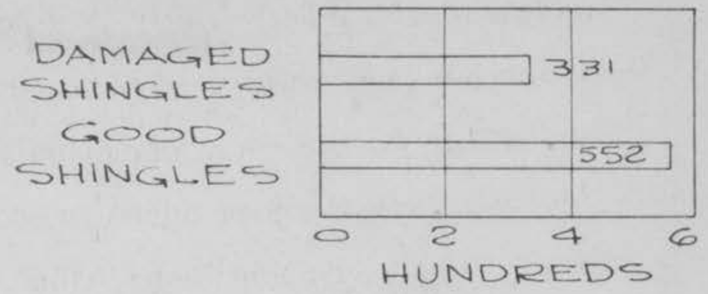


FIG 32. NO. NAILS PER SQUARE

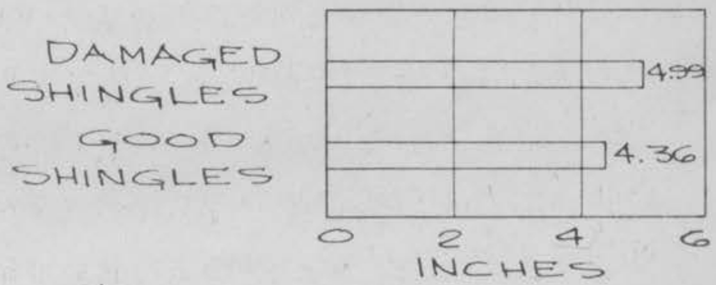


FIG. 33. INCHES OF EXPOSURE

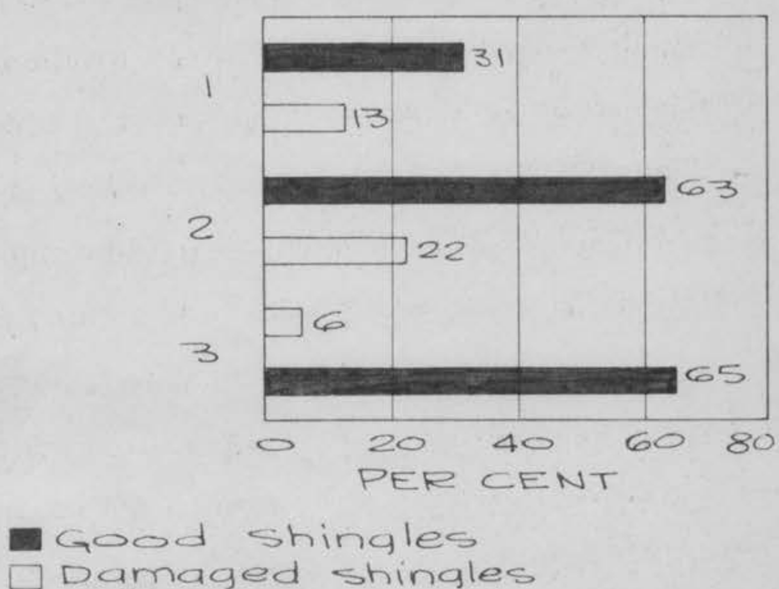


FIG. 34. NO. PLY COVERAGE

had less exposure than the double or single coverage shingles and this was the factor that contributed to their lasting ability and not the amount of coverage.

In all cases the good asphalt shingle was fastened by a galvanized nail.

The number of nails per square averaged 552 as is shown in Figure 32 and Table IV. In all cases it was universally found that more nails were used in these good shingles examined than was recommended by manufacturers at the time of installation.

Solid sheathing predominates as the best type of deck for good asphalt shingles. The good shingles were over a solid sheathing on 76 percent of the roofs examined. This is shown in Figure 37 and Table IV. Wood shingles under the asphalt shingles accounted for the other 24 percent of the decks. Solid sheathing offered a better nailing surface and a much better surface in case of hail. This can account for the much higher percentage of solid sheathing over the average of all roofs examined. Wood shingles as a surface on which to lay asphalt shingles were found to be susceptible to hail damage as shown in Figure 71 and were not as secure a deck to nail to as solid sheathing.

The age of the deck averaged 28 years for all good asphalt shingle roofs. As 76 percent of the roofs were laid over solid sheathing, the age of the deck was the same as

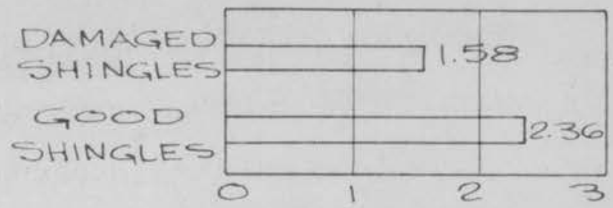


FIG. 35. LB. PULL TO LIFT TAB

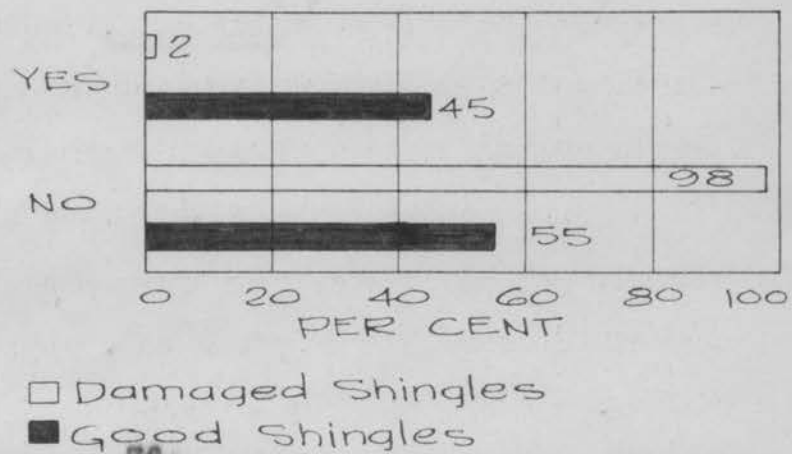


FIG. 36. DID SHINGLES SEAL

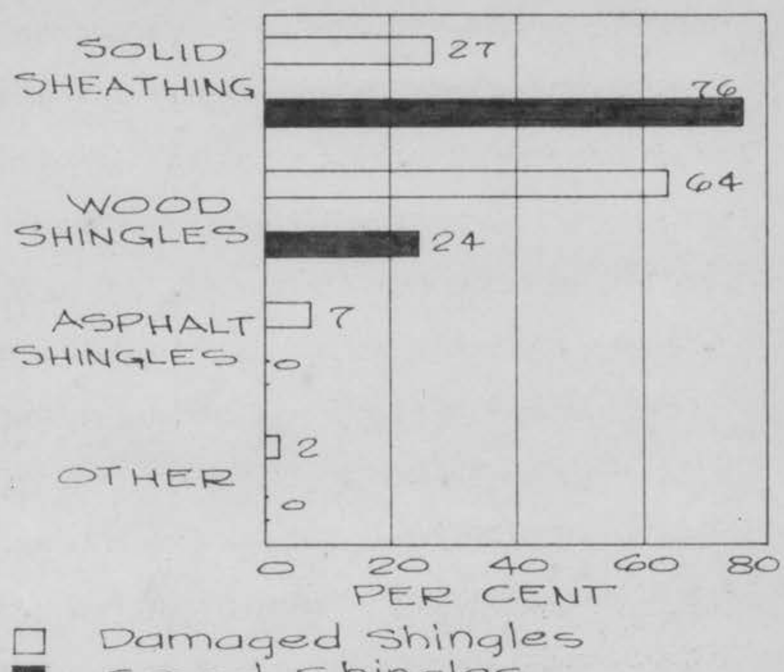


FIG. 37. TYPE OF DECK

the shingle. In the other 24 percent of the roofs, which were wood shingles, the age of the wood shingles was 45 years. This age includes the time that they have been covered with asphalt shingles.

Whether a shingle has sealed itself was an important factor as to the ability of an asphalt shingle to stay on the roof. Fifty-five percent of the good asphalt shingles were found to have sealed themselves while 45 percent were not sealed. This is shown in Figure 36 and Table IV. Shingles at the present time are not manufactured to seal as they are coated with mica or talc to eliminate this possibility of sealing in shipping and storage. In the past some companies manufactured shingles that had a low melting asphalt on their backs and this tended to cause the shingle to seal. However, much trouble was caused in shipping and storage if the shingle would seal; and, to eliminate any possibility of trouble, they have been manufactured to give complete separation when taken from the bundle.

Nails were driven in perpendicular to the roof in all cases of good roofs.

The pounds pull to lift the tab through 4.25 inches is shown in Figure 35 and the average of 2.36 pounds is shown in Table IV. An apparatus as shown in Figure 15 was built to lift the tab and was used on all shingles except those that were sealed down. In some cases at high temperature only 0.5 pound pull was recorded and at lower temperatures as high as 4.0 pounds was required to lift the tab.

The temperatures varied from 55° F. to 140° F. and had an average temperature of 97° F. on the roof. Figure 26 shows the curve formed with the various temperatures and pounds pull. Table IV shows first the average air temperature and second the average roof temperature.

Damaged roofs

Location. Damaged shingles were found on 172 buildings in 69 counties in Iowa as shown in Figure 7. Any roof with any amount of damage from one percent to 100 percent was examined whenever possible. Roofs were not selected with any type shingle or with any type building in mind. Data were collected on all damaged shingles as seen. There was no compilation of data until the work was finished which might have caused an opinion being formed as to pattern type, type of building or age of roof that could be correlated with other studies.

The percentages of farms that were operated by owner-operators and tenant-operators were 57 percent and 43 percent, respectively, as shown in Figure 20 and Table VI. This percentage is relatively close to the state average, which is 48.3 percent for owner-operator and 51.7 percent for tenant-operator farms. The percentage could have been

Table VI. Questionnaire of Damaged Shingles by Percent

WIND AND HAIL LOSSES TO ASPHALT SHINGLES

I. Sample Number and Date
   1. Sample number______
   2. Year, month, day______
II. Location
   1. Location of farm. County______ ( )
   2. Farm operated by (a) Owner 57 (b) Tenant 43
   3. Name of Owner______
   4. Protection for bldg. (a) Windbreak 29 (b) Hill 1
      (c) Other bldgs. 13 (d) None 57
   5. Direction of exposure. N 18, S 26, E 19, W 37
   6. Direction of wind. N 31, S 31, E 1, W 37
   7. Location of damage (a) Ridge 25 (b) Center 60
      (c) Bottom 3 (d) Side 12
   8. Who applied shingles? (a) Owner 8 (b) Carpenter 86
      (c) Contractor 5 Other 1
III. Building characteristics
   1. Type of building (a) Dwelling 64 (b) Barn 16 (c) Machine shed 2 (d) Hog house 3 (e) Poultry house 3
      (f) Crib and granary 2 (g) Other 10
   2. Type of roof. (a) Flat 99, and (b) Curved 1
   3. Slope of roof, degrees 38
   4. Was a starter strip used? Yes 0 No 100
   5. Was roofers felt used? Yes 8 No 92
IV. Shingle characteristics
   1. Type of shingle (a) Square tab 60 (b) Hexagonal 22
      (c) Other 18
   2. Age of shingle, years 7.03
   3. Thickness of shingles, inches 0.158
   4. Inches shingles are exposed to weather 4.99
   5. Inches nails are from edge of shingle 6.12
   6. Number of plys of coverage, 1 31, 2 63, 3 6, 4 0
   7. How the shingle is fastened. (a) Galvanized nail 99
      (b) Other type nail______ (c) Clips______ (d) Cement 1
      (e) Other______
   8. Number of nails per square 331
   9. Type of deck. (a) Solid sheathing 27 (b) Wood shingles 64
      (c) Asphalt shingles 7 (d) Other 2
   10. Age of deck, years 26.7
   11. Have shingles sealed themselves? Yes 2 No 98
   12. At what angle are nails driven? 90
   13. Pounds pull to lift shingle 1.58
   14. Temperature on roof 71 - 99
V. Failure
   1. Cause of failure. (a) Nails pulled through 6 (b) Nails pulled out 4 (c) Broke 81 (d) Other 9
   2. Amount of damage, percent 9.9
   3. Type of damage (a) Spots 87 (b) One area 13
   4. Were there previous claims? Yes 28 No 72
   5. Age when previous claims occurred, years 6.4
VI. Remarks

closer but a tendency to inspect roofs on farms on which the owner operated the farm was necessary to be able to gather the required information. A number of farms were by passed when the person at home said he was a renter and knew nothing about the damaged asphalt shingles.

No protection for the building upon which the damage occurred was very prevalent in this study. As shown in Figure 14 and Table VI, no protection for the roofs occurred 57 percent, windbreaks were present 29 percent of the time, and other buildings offered protection in 13 percent of the cases. A good windbreak would be worth a good deal to a farmstead if only the lessening of damage to asphalt shingles were to be taken into consideration.

A western exposure on the roofs was damaged in more instances than were any of the other exposures. However, the western exposure had only 37 percent of the losses. The northern exposure was damaged in 18 percent, the southern in 26 percent, and the eastern in 19 percent of the cases, as is shown in Figure 40 and Table VI.

A westerly wind caused the most damage, whereas an easterly wind caused practically none. The same percentage of direction of wind as the direction of exposure for the west must have been a coincidence as not all the damage done by a westerly wind did damage to the western exposure. This part of the data collected cannot be taken as 100

Table VII. Questionnaire of Damaged Shingles by Number

WIND AND HAIL LOSSES TO ASPHALT SHINGLES

I. Sample Number and Date
   1. Sample number__________
   2. Year, month, day__________
II. Location
   1. Location of farm. County__________( )
   2. Farm operated by (a) Owner 72 (b) Tenant 54
   3. Name of Owner__________
   4. Protection for bldg. (a) Windbreak 38 (b) Hill 1
      (c) Other bldgs. 17 (d) None 76
   5. Direction of exposure. N 23, S 34, E 25, W 48
   6. Direction of wind. N 32, S 32, E 1, W 39
   7. Location of damage (a) Ridge 32 (b) Center 77
      (c) Bottom 4 (d) Side__________
   8. Who applied shingles? (a) Owner 9, (b) Carpenter 103
      (c) Contractor 7, Other 1
III. Building characteristics
   1. Type of building (a) Dwelling 83 (b) Barn 21 (c) Machine
      shed 3 (d) Hog house 4 (e) Poultry house 4
      (f) Crib and granary 3 (g) Other 11
   2. Type of roof. (a) Flat 127, and (b) Curved 2
   3. Slope of roof, degrees 38
   4. Was a starter strip used? Yes 0 No 129
   5. Was roofers felt used? Yes 11 No 118
IV. Shingle characteristics
   1. Type of shingle (a) Square tab 81 (b) Hexagonal 29
      (c) Other 24
   2. Age of shingle, years 7.03
   3. Thickness of shingles, inches 0.158
   4. Inches shingles are exposed to weather 4.99
   5. Inches nails are from edge of shingle, 6.12
   6. Number of plys of coverage, 1 43, 2 87, 3 8, 4 0
   7. How the shingle is fastened. (a) Galvanized nail 136
      (b) Other type nail 0 (c) Clips 0 (d) Cement 1
      (e) Other 0
   8. Number of nails per square 331
   9. Type of deck. (a) Solid sheathing 35 (b) Wood shingles 84
      (c) Asphalt shingles 10 (d) Other 2
   10. Age of deck, years 26.7
   11. Have shingles sealed themselves? Yes 3 No 117
   12. At what angle are nails driven? 90
   13. Pounds pull to lift shingle 1.58
   14. Temperature on roof 71 - 99
V. Failure
   1. Cause of failure. (a) Nails pulled through 8 (b) Nails pulled
      out 6 (c) Broke 109 (d) Other 12
   2. Amount of damage, percent 9.9
   3. Type of damage (a) Spots 109 (b) One area 17
   4. Were there previous claims? Yes 31 No 78
   5. Age when previous claims occurred, years 6.4
VI. Remarks

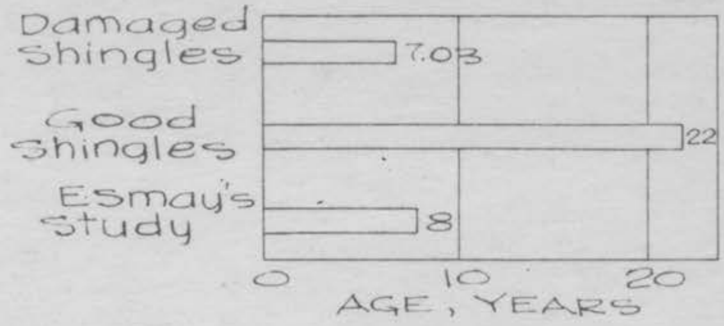


FIG. 38. AGE OF SHINGLES

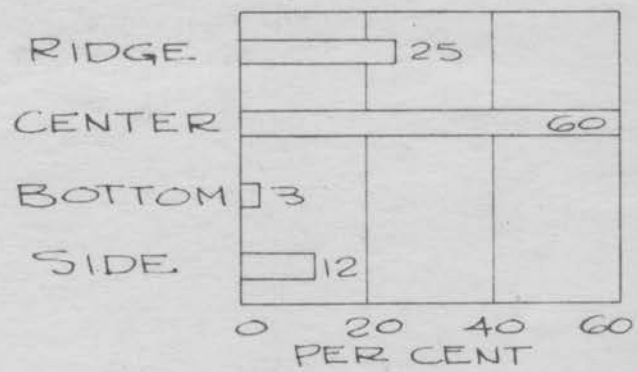


FIG. 39. LOCATION OF DAMAGE

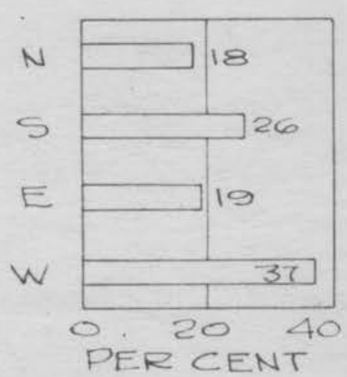


FIG. 40. DIRECTION OF EXPOSURE OF DAMAGED

percent accurate as the memory of the people cannot be considered very accurate; however, it mighh have a compensating error which would give a general trend in the over-all number of cases examined.

The location of the damage to the shingles on the roof was as is shown in Figure 39 and Table VI. The center, which covers a much larger area on a roof than does the edge, bottom or ridge, showed 60 percent of the position of damage. The ridge was next with 25 percent, the side had 12 percent and the bottom 3 percent of the damage. The location of the damage in many instances could be laid to poor workmanship in that area and also to other obstacles, such as trees, valleys and other buildings, causing wind to catch a certain part of the roof.

As in the application of good asphalt shingles, carpenters applied the greater part or 86 percent of the damaged asphalt shingles. This is shown in Table VI.

Building characteristics. According to the study by Esmay (3) it was shown that 53.4 percent of all buildings with asphalt shingles that were damaged in 1946 were dwellings. This is relatively close to the percentage (64 percent) found in this study. The percentage found for various buildings in this study is shown in Figure 41 and Table VI, and for Esmay's study in 1946 in Figure 41. Some buildings on a farm are not as easily discernible as others

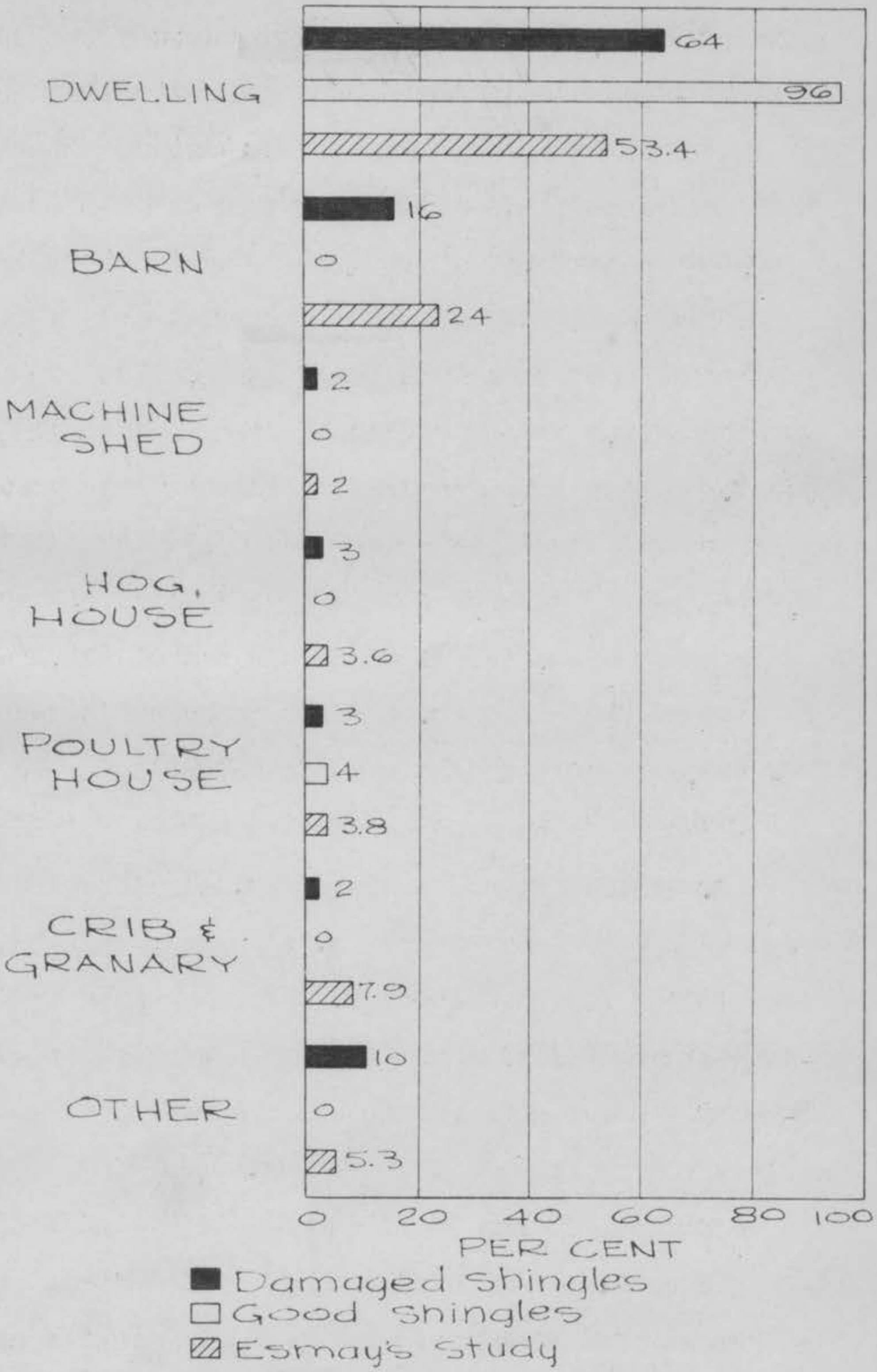


FIG. 41. TYPE OF BUILDING

and the usage of other buildings, such as churches, schools and oil stations, undoubtedly caused the variance in the percentages of Esmay's and the author's study, exclusive of dwellings.

Flat roofs were found in 99 percent of the cases of asphalt shingle failures and curved roofs were found one percent of the time. There were but two round roofs found damaged in this study and it was not the fact that the roofs were round that the asphalt shingles failed.

Slopes of roofs varied from 10° to 60° with the average slope at 38°. Flatter sloped roofs weather more readily and can catch wind more easily but they also seal more often. It was not an easy fact to determine as to whether slope was responsible for a good or damaged asphalt shingle roof as far as the wind resisting qualities were concerned.

No starter strips were used and only 8 percent of the damaged roofs employed the use of a roofers felt. These two pieces of merchandise have seemed to be more recent innovations.

Shingle characteristics. Shingle losses by percent as far as type was concerned were much the same as the percent of the general trend in usage in Iowa. Figure 43 shows the percents of good, damaged and state average of asphalt shingles.

Esmay (3) found that the average age of damaged asphalt

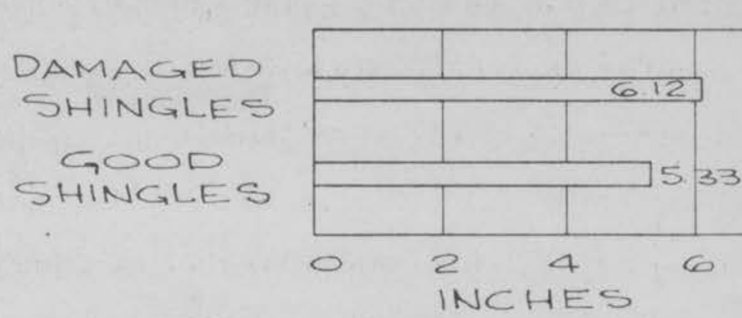


FIG. 42. INCHES NAILS ARE FROM EDGE OF SHINGLE

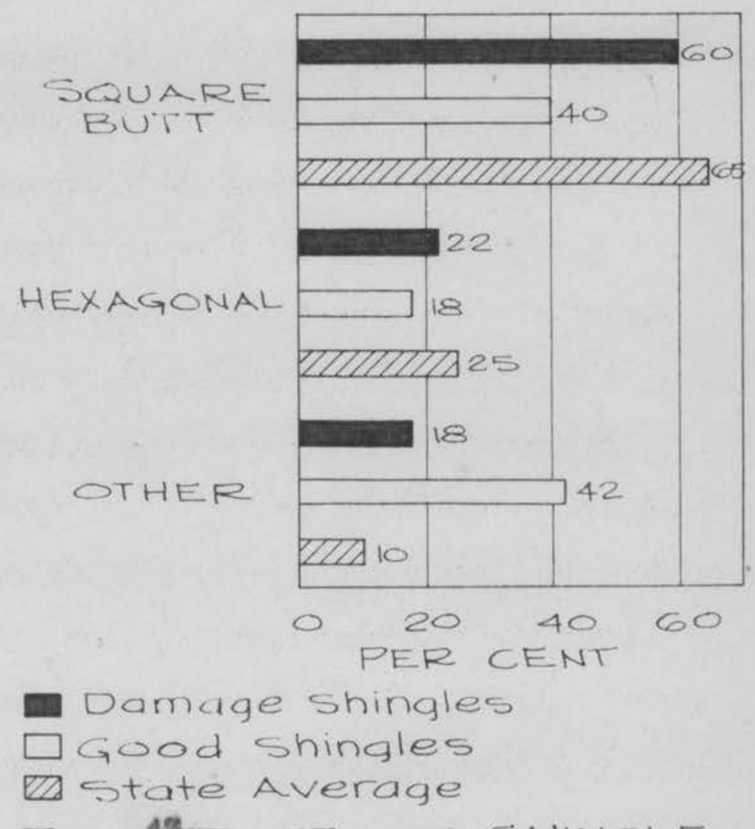


FIG. 43. TYPE OF SHINGLE

shingles in 1946 was approximately eight years. The average age of the damaged asphalt shingles in the author's study was 7.03 years as shown in Figure 38 and Table VI. There seems to be some discrepancy between the author's study and Emmay's (3), but this difference is not too significant.

The average thickness was 0.158 inches for the damaged shingles, as is shown in Figure 27 and Table VI. This is relatively close to the average thickness (0.152 inches) of present day shingles being sold.

Exposure to the weather was 4.99 inches as shown in Figure 33 and Table VI. This was slightly higher than the average shingle should be exposed if the percentages of damaged square butt and hexagonal shingles had been applied as recommended at 5 inches and 4.67 inches, respectively. There were also a number of square butt shingles with four inch exposure that failed. The average exposure should have been about 4.8 inches.

The distance that the nails were from the edge of exposure was 6.12 inches for the damaged shingles. This is shown in Figure 42 and Table VI. The average distance should have been about 5.4 inches which is approximately three-quarters of an inch less than was found. Some shingles were found to be nailed as high as 10 inches from the edge of exposure and this type of shingle offered little resistance to bending.

Two ply coverage was found in 63 percent of the cases which is nearly right for the patterns found. The number of plys of coverage is shown in Figure 34 and Table VI. Square butt shingles with five inch exposure were listed as 2 ply coverage and those with four inch exposure as 3 ply coverage. Hexagonal shingles were noted as one ply coverage.

If all shingles had been applied as recommended by the Asphalt Roofing Industry Bureau at the present time, the average number of nails would have been 445 nails per square, whereas the average was but 331 nails per square as is shown in Figure 32 and Table VI. The average number that should have been applied as was commonly recommended in the years prior to the war would have been about 327 nails per square. In the years prior to the war it was recommended that four nails per strip shingle be used for both hexagonal and square butt asphalt shingles. Therefore, it can be seen that a rather close approximation of nails were used as was recommended.

As shown in Figure 37 and Table VI, wood shingles as a deck to which the damaged asphalt shingles were applied were used 64 percent of the time. Asphalt shingles were in evidence 7 percent, solid sheathing 27 percent, and roll roofing 2 percent of the cases investigated.

The average age of the deck was 26.7 years. In the case of wood shingles as a deck it was found that houses were replaced when 28.6 years old, all other wood shingle decks at 37.3 years, and the average age was 31 years.

Practically no damaged asphalt shingles were found that had sealed themselves. Figure 36 and Table VI show that only 2 percent had sealed, whereas 98 percent had not sealed down. As most damaged shingles had not been on a roof too long and it generally requires quite a few years for sealing to start, it was not surprising that this percentage is low. Also, due to the fact that a sealed shingle is hard to blow off a roof has considerable to do with it.

The angle at which nails were driven was found significant when they were not driven at 90°. In only two instances was failure noted due to the fact that nails were not being driven perpendicular. Whenever nails are not driven perpendicular it causes the nail head to cut the shingle and make it much easier to fail.

In Figure 35 the pounds pull that was required to lift a tab through 4.25 inches is shown and in Table VI the average is shown as 1.58 pounds. All tabs were lifted by the apparatus as shown in Figure 15.

Asphalt shingles get a good deal warmer than air temperature as is shown in Table VI. The average temperature on the shingles was 99° F., whereas the average air temperature was 71° F. This difference of 28° F. makes a shingle very pliable and the pounds pull required to lift the shingle through 4.25 inches decreases as the temperature increases. This is shown on a curve in Figure 26.

Failure. The causes of failure were as follows: (1) nails pulled through, 6 percent; (2) nails pulled out, 4 percent; (3) broken, 81 percent; (4) other, 9 percent; and are shown in Table VI. Breakage is by far the greatest cause of failure, but the original reason for the shingle to have motion and to break was not always discernible.

About 10 percent damage per roof was estimated as the amount of failure. Damage varied from less than one percent to a 100 percent loss. A 100 percent loss was only due to hail damage and in no instances did wind approach this amount of damage.

Damage seemed to be in spots 87 percent of the time and the rest of the time it was concentrated in one area. In most instances where damage occurred in one area the spot was rather small. Damage could generally be accounted for in spots due to the various reasons of failures such as improper nailing, improper exposure and a poor deck on which to nail.

In 28 percent of the failures it was a repeat case and the age at which the former failure occurred was but 0.63 of a year prior to the second failure. The evidence of poor repair work and more failures due to the original cause of failure were commonly observed. Repair work was noted as slipshod and the checking of the whole roof area at the time of repair was not adequate.

Lumber dealers

The lumber dealers that were queried as to the questions on the questionnaire in Table VIII were located in towns of less than 8,000 people. This was done in order that their trade would be with farmers to a large extent. A representative sample of the state was attempted as is shown in Figure 9. In nearly all instances either the manager or owner was questioned as to his opinion of the proper or improper method of application of asphalt shingles.

The first question that was always asked was the dealer's opinion as to the cause of asphalt shingle's failure. The breakdown is rather varied as to opinions. The three most prominent faults were in application. These were, (1) too few nails, 25 percent; (2) tabs not fastened down, 25 percent; (3) too high nailing, 20 percent. Other causes in order of failure were too much exposure, not heavy enough, miscellaneous reasons, improper type of shingle, poor material, and two percent said they never had any trouble.

The question as to whether weight is a factor in keeping a shingle on a roof was answered as is shown in Figure 46, with 73 percent believing it was and 27 percent believing

Table VIII. Questionnaire of Lumber Dealers by Percent

Wind and Hail Losses to Asphalt Shingles

1. Name____

2. Address______________________________________

3. Dealer's opinion as to cause of asphalt shingle's failure

____

4. Is the weight per square a factor? Yes 73 No 27

5. Weight of shingle per square recommended. Less than 210# 9 , More than 210# 50, 210# 41.

6. Number of inches of exposure recommended. 4" 41, 5" 59.

7. Number of nails per shingle recommended. 4 23, 6 77.

8. Is a starter strip recommended? Yes 29, No 71.

9. Is a roofer's felt recommended? Yes 77, No 23.

10. Is the angle at which nails are driven a factor? Yes 80, No 20.

11. Have you used clips? Yes 34, No 66.

12. Do you recommend clips? Yes 53, No 47.

13. Have you used cement? Yes 74, No 26.

14. Do you recommend cement? Yes 92, No 8.

15. At the time of application, is weather a factor? Yes 93, No 7.

16. Have you used a lock-corner shingle? Yes 55, No 45.

17. Do you recommend a lock-corner shingle? Yes 47, No 53.

18. Do shingles seal themselves? Yes 63, No 47.

Table IX. Questionnaire of Lumber Dealers by Number

Wind and Hail Losses to Asphalt Shingles

1. Name______________________________

2. Address______________________________

3. Dealer's opinion as to cause of asphalt shingle's failure

____

4. Is the weight per square a factor? Yes 48, No 17.

5. Weight of shingle per square recommended. Less than 210# 6, More than 210# 33, 210# 27.

6. Number of inches of exposure recommended. 4" 27, 5" 38.

7. Number of nails per shingle recommended. 4 15, 6 51.

8. Is a starter strip recommended? Yes 19, No 47.

9. Is a roofer's felt recommended? Yes 50, No 15.

10. Is the angle at which nails are driven a factor? Yes 50, No 12.

11. Have you used clips? Yes 21, No 40.

12. Do you recommend clips? Yes 19, No 17.

13. Have you used cement? Yes 46, No 16.

14. Do you recommend cement? Yes 48, No 4.

15. At the time of application, is weather a factor? Yes 55, No 4.

16. Have you used a lock-corner shingle? Yes 35, No 28.

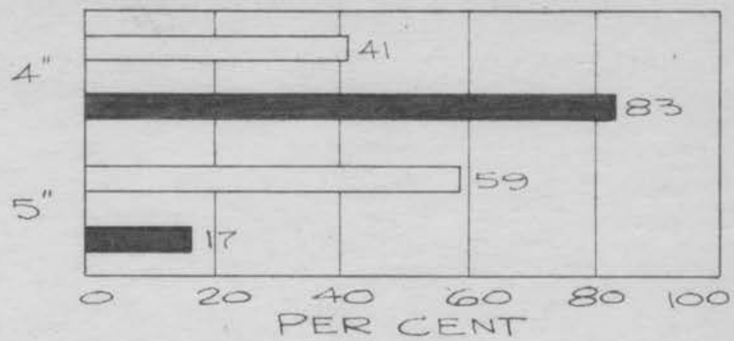
17. Do you recommend a lock-corner shingle? Yes 26, No 29.

18. Do shingles seal themselves? Yes 40, No 23.

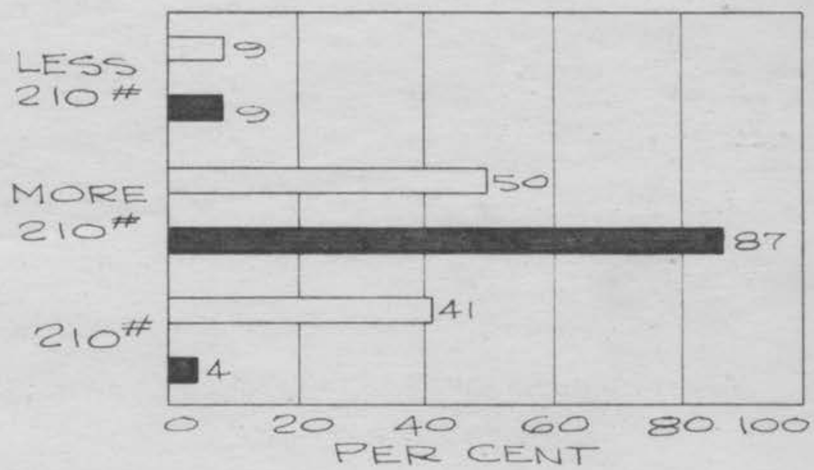
it was not a factor. Weight per square is the weight of the total number of shingles required to cover 100 square feet in the manner the asphalt shingles were designed. The group that did not believe weight per square was a factor were those dealers that liked an interlocking shingle or one that could be clipped or cemented down.

The weight per square recommended that each lumber dealer believed should be used is shown in Figure 45 and Table VIII. Fifty percent of the dealers recommend a type shingle that would weigh more than 210 pounds, 41 percent recommended a 210 pound weight, and the other 9 percent recommended less than 210 pounds per square. In many instances the weight recommended was the weight that the dealer handled and sincerely believed that the weight recommended was the correct weight with probably little basis of facts for his beliefs.

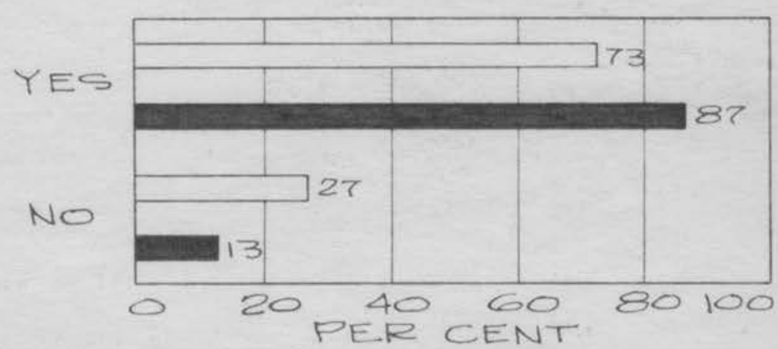
The square butt asphalt shingle which assimilates the pattern of a wood shingle was by far the most common pattern sold and recommended by lumber dealers. The square butt shingle can be exposed with five inches or less exposure. The four inch exposure is the most commonly used exposure whenever the five inch exposure is not used. Nearly all asphalt square butt shingles are patterned to be laid with five inch exposure. As is shown in Figure 44 and Table VIII 41 percent of the lumber dealers believed that the square



□ Lumber Dealers
■ Insurance Agents
FIG. 44. INCHES RECOMMENDED



□ Lumber Dealers
■ Insurance Agent
FIG. 45. WEIGHT RECOMMENDED



□ Lumber Dealers
■ Insurance Agents
FIG. 46. IS WEIGHT A FACTOR

butt shingle should be laid with four inch exposure, whereas 59 percent believed that it should be laid with a five inch exposure.

In the years following the war six nails per strip of square butt asphalt shingle have been recommended instead of four nails as were formerly used. The nailing patterns are shown in Figure 47. In Figure 52 and Table VIII it is shown that 23 percent of the dealers recommend the use of four nails and 77 percent recommend the use of six nails.

Starter strips were recommended by 29 percent and were not recommended by 71 percent of the dealers. Most dealers recommend the usage of a reversed asphalt strip shingle as a starter strip in lieu of a starter strip. Starter strips are recommended by the Asphalt Roofing Industry Bureau (7), but the use of the starter strip has not seemed to take hold with lumber dealers.

The usage of a 15 lb. roofers felt over a tight sheathed deck was recommended by 77 percent of the lumber dealers while 23 percent do not recommend its usage. A roofers felt is recommended by the Asphalt Roofing Industry Bureau (7) to protect the deck from dampness.

Nails that are not driven in straight cause the head to cut the shingle as is shown in Figure 30 and offers less resistance to holding the shingle on the roof. To determine if this was realized by lumber dealers, the

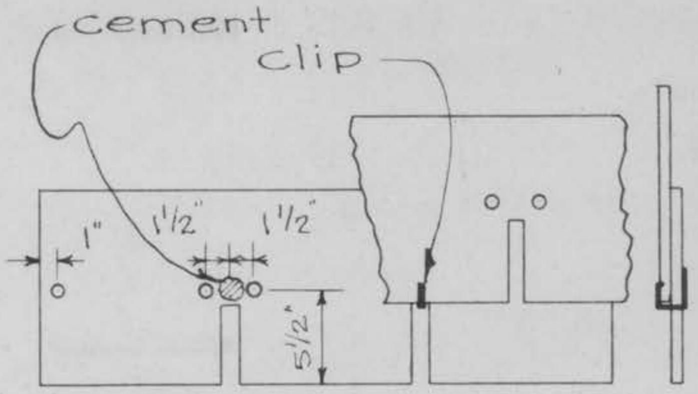


FIG. 47. 12 x 36 SQUARE BUTT

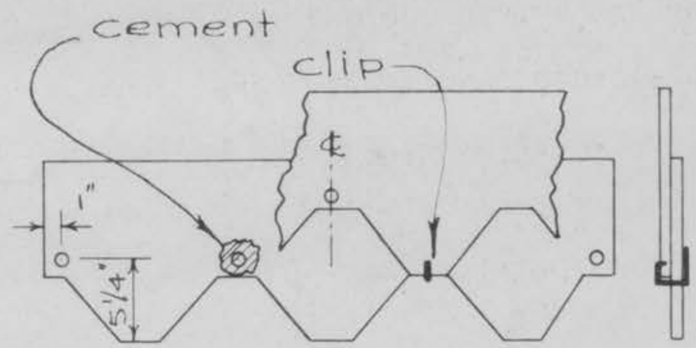


FIG. 48. 3 TAB HEXAGONAL

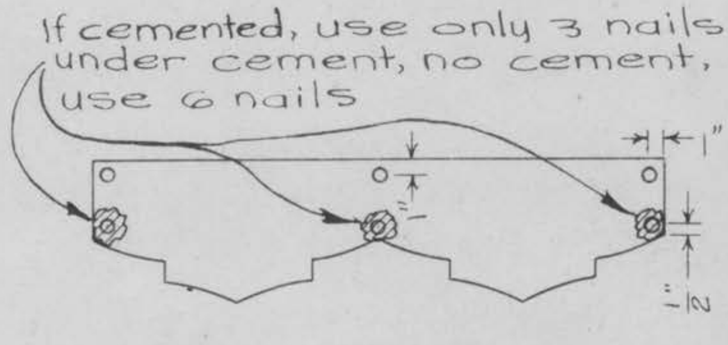
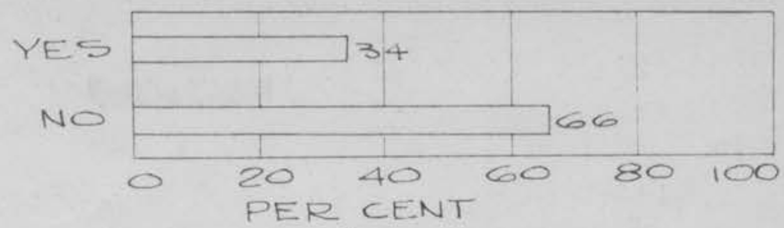
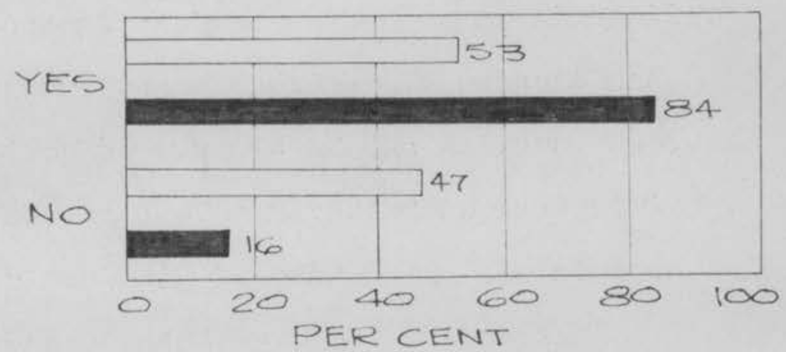


FIG 49. THATCH TYPE 10 X 36



☐ Lumber Dealers

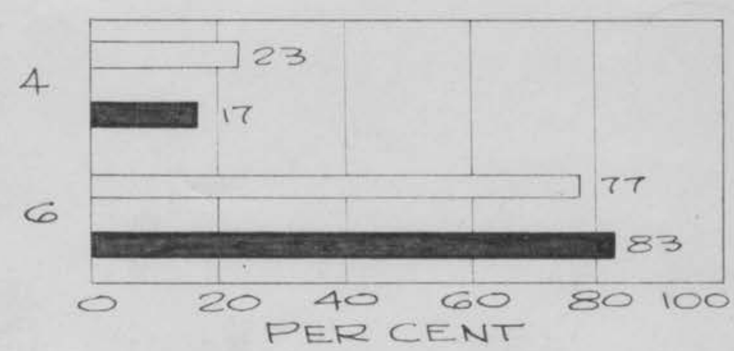
FIG. 50 HAVE YOU USED CLIPS



☐ Lumber Dealers

■ Insurance Agents

FIG. 51. DO YOU RECOMEND CLIPS



☐ Lumber Dealers

■ Insurance Agents

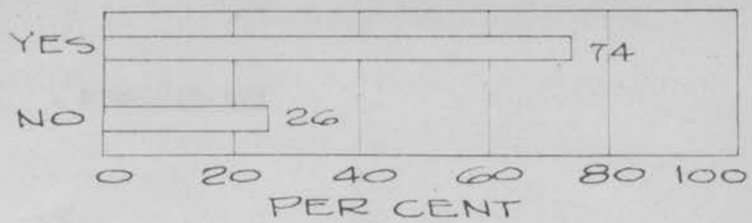
FIG. 52. NO. NAILS RECOMMEND

question was asked, "Is it a factor at what angle a nail is driven into a shingle?" As is shown in Table VIII, 80 percent realized that it did make a difference, while 20 percent did not.

Clips such as those shown in Figure 29 are used to fasten a tab to the strip below and cause motion to be stopped vertically but do not cause motion to be stopped in any horizontal dirdction. Only 34 percent of the dealers have ever used clips as Figure 50 shows. The clips are made of a non-corrosive metal material and will work equally well on either a square butt or a hexagonal asphalt shingle.

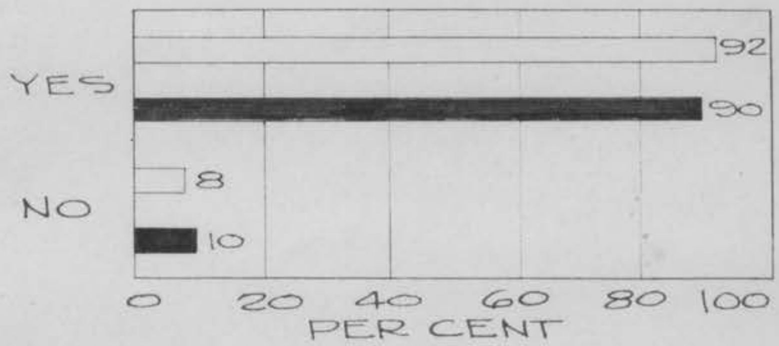
Though only 34 percent of the dealers have used clips, Figure 51 shows that 53 percent recommended their use. Forty-seven percent of the lumber dealers do not recommend their use--the reasons given, that clips are not necessary, clips add too much to the cost, the dealer did not know anything about them, or that clips will spoil the looks of the roof. The cost per square was found to be from $0.60 to $1.00 for the clips.

A much higher percentage of the dealers had used cement than had used clips. Figure 53 and Table VIII show that 74 percent had used cement. Figure 54 and Table VIII show that 92 percent of the dealers recommended the use of cement. Cement is used under each tab as shown in Figures 47 and 48 to fasten the tab securely to the roof. The



□ Lumber Dealers

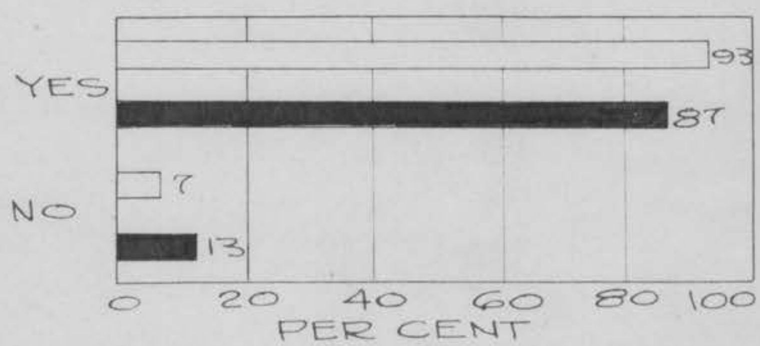
FIG. 53. HAVE YOU USED CEMENT



□ Lumber Dealers

■ Insurance Agents

FIG. 54. DO YOU RECOMMEND CEMENT



□ Lumber Dealers

■ Insurance Agents

FIG. 55. IS WEATHER A FACTOR AT APPLICATION

cement is applied with a putty knife or a caulking gun. The cost for the material per square of shingles varies from $0.40 to $0.80. Care must be taken in application or an unsightly roof, as shown in Figure 59, might be installed.

The weather seems to be an important factor whether an asphalt shingle gives good service or not. Figure 55 shows that 9% percent of the lumber dealers believe that with improper weather such as too cold, too wet, too windy and dusty, or too hot, an asphalt shingle could give trouble.

Interlocking shingles, an example shown in Figure 56, are manufactured by a number of leading asphalt roofing companies. This type shingle is so designed that the edges of the shingles are fastened and cannot blow up and off as in the more common patterns such as a square butt or hexagonal asphalt shingle. Figure 60 and Table VIII show that 55 percent of the dealers have used this pattern shingle, whereas it is shown in Figure 61 and Table VIII that only 47 percent recommended its use. The reason for its use was its ability to withstand wind and the reasons for not using it, were its appearance, difficulty to repair when damaged and the initial application.

As has been stated before, asphalt shingles should not seal down due to mica or talc on the strip shingle. However,

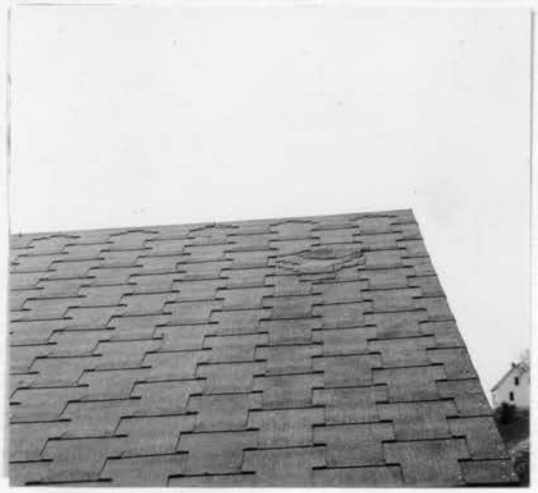


Fig. 56. A Tite-on Shingle

Fig. 57. A Thatch Type Shingle

Fig. 58. An Interlocking Pattern Shingle

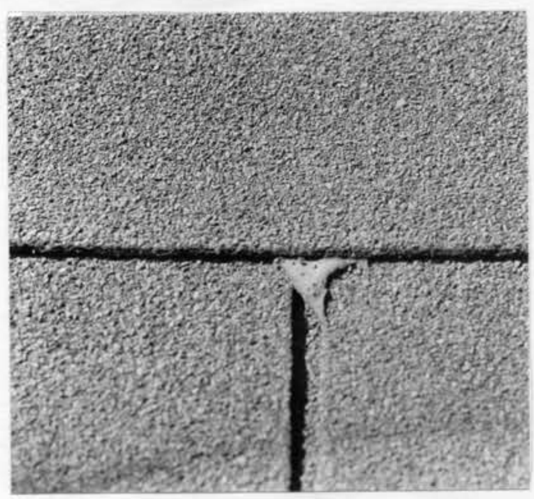
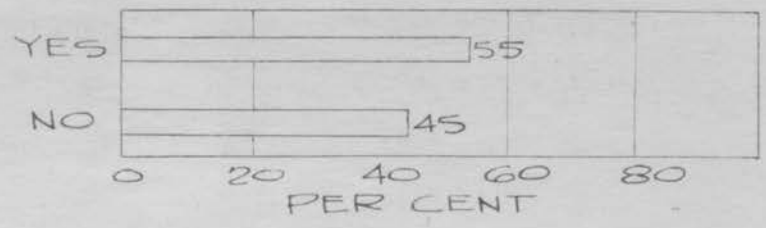
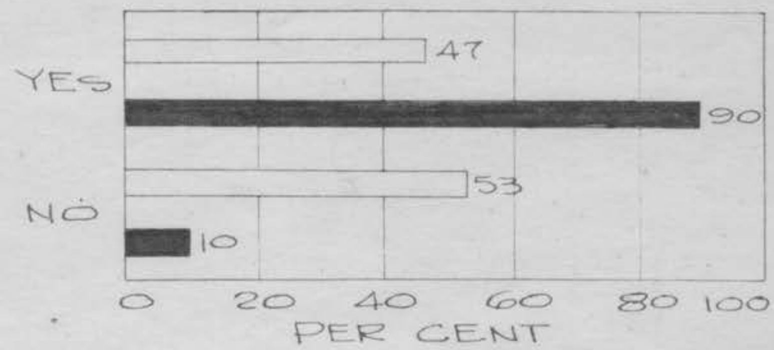


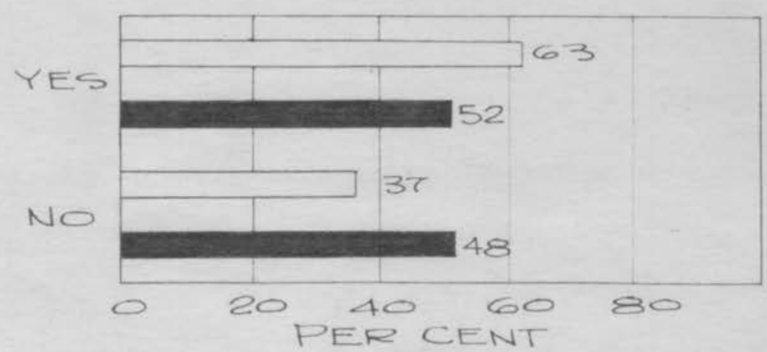
Fig. 59. Careless Cementing of Tabs



□ Lumber Dealers
FIG. 60. HAVE YOU USED A LOCK-CORNER SHINGLE



□ Lumber Dealers
■ Insurance Agents
FIG. 61. DO YOU RECOMMEND LOCK-CORNER SHINGLES



□ Lumber Dealers
■ Insurance Agent
FIG. 62. DO SHINGLES SEAL THEMSELVES

63 percent of the lumber dealers, as shown in Figure 62, have seen shingles seal down, and this was very probably true as it has been seen in a number of instances by the author. The sealing effect takes place if the shingles are highly exposed to the sun. Asphalt will melt out of the shingle and cause a sealing effect to take place.

Insurance agents

Representatives of the Iowa Mutual Tornado Insurance Association were contacted whenever possible and asked as to their opinions and recommendations of asphalt shingles. The various counties in which they were contacted are shown in Figure 9 and their answers are in Table X. In all instances the secretaries of the local county mutual companies were the men questioned.

Eighty-seven percent of the insurance agents believed that weight was a factor as shown in Figure 46 in keeping a roof from being damaged by hail or wind. The rest who did not think so recommended the use of an interlocking shingle, a clip to fasten the tabs down or cement to fasten the tabs.

The same percentage (87) that believed weight is a factor also believed that the heaviest weight shingle that could be purchased or those heavier than 210 pounds per square should be recommended.

In like consideration that a heavy weight per square was needed, Figure 44 shows that 83 percent recommended that a square butt shingle be laid with a four inch exposure. The other 17 percent who recommended a five inch exposure did so as they thought an asphalt shingle should be applied as it was manufactured to be laid.

Most (83 percent) of the insurance agents recommended that six nails be used in a square butt strip shingle. They more nearly fell into line with the manufacturer's specifications than did the lumber dealers with 77 percent.

Insurance agents highly recommended the use of clips and cement as they believed that any method to keep the tabs from blowing up and off a roof should be used. Figure 51 shows that 84 percent recommended clips and Figure 54 shows that 90 percent recommended cement to fasten the tabs down.

Weather again seemed to be an important factor in the good application of asphalt shingles. The insurance agents believed the proper weather, a still day with temperature from 70-85° F. in the spring and early summer, was a factor, as is shown in Figure 55.

Any method that could keep a shingle from blowing off was recommended by insurance agents. Ninety percent, as shown in Figure 61, recommended the use of an interlocking shingle for that reason as they had highly recommended the use of clips and cement.

Table X. Questionnaire of Insurance Agents by Percent

Wind and Hail Losses to Asphalt Shingles

1. Name______________________________
2. Address____________________________
3. Dealer's opinion as to cause of asphalt shingle's failure

   ____
4. Is the weight per square a factor? Yes 87, No 13.
5. Weight of shingle per square recommended. Less than 210# 9, More than 210# 87, 210# 4.
6. Number of inches of exposure recommended. 4" 83, 5" 17.
7. Number of nails per shingle recommended. 4 17, 6 83.
8. Is a starter strip recommended? Yes ___, No ___.
9. Is a roofer's felt recommended? Yes ___, No ___.
10. Is the angle at which nails are driven a factor? Yes ___, No ___.
11. Have you used clips? Yes ___, No ___.
12. Do you recommend clips? Yes 84, No 16.
13. Have you used cement? Yes ___, No ___.
14. Do you recommend cement? Yes 90, No 10.
15. At the time of application, is weather a factor? Yes 87, No 13.
16. Have you used a lock-corner shingle? Yes ___ No___.
17. Do you recommend a lock-corner shingle? Yes 90, No 10.
18. Do shingles seal themselves? Yes 52, No 48.

Table XI. Questionnaire of Insurance Agents by Number

Wind and Hail Losses to Asphalt Shingles

1. Name____________________________________
2. Address__________________________________
3. Dealer's opinion as to cause of asphalt shingle's failure
____
4. Is the weight per square a factor? Yes 20, No 3.
5. Weight of shingle per square recommended. Less than 210# 2, More than 210# 20, 210# 1.
6. Number of inches of exposure recommended. 4" 20, 5" 4.
7. Number of nails per shingle recommended. 4 4, 6 19.
8. Is a starter strip recommended? Yes___ No___.
9. Is a roofer's felt recommended? Yes___ No___.
10. Is the angle at which nails are driven a factor? Yes___ No___.
11. Have you used clips? Yes 11 No 2.
12. Do you recommend clips? Yes___ No___.
13. Have you used cement? Yes___ No___.
14. Do you recommend cement? Yes 17 No 2.
15. At the time of application, is weather a factor? Yes 20 No 3.
16. Have you used a lock-corner shingle? Yes___ No___.
17. Do you recommend a lock-corner shingle? Yes 18 No 2.
18. Do shingles seal themselves? Yes 12 No 11.

About one-half of the insurance agents, as shown in Figure 62, believed that a shingle will seal down under certain circumstances. The percentages as shown in Figure 62 and Table X are not to be construed as the amount of roofs that seal but rather that percentage of lumber dealers or insurance agents that have seen an asphalt shingle seal down.

Laboratory Study

Physical analysis

A very preliminary study of the physical makeup of asphalt shingles was made from three damaged samples inspected in the fall of 1947. The thickness per shingle and the average weight per square for each type of material are shown in Table XII.

Table XII. The Physical Makeup in Pounds per Square Foot

Sample number	Average thickness	Average weight	Weight large granules	Weight fine granules	Weight felt	Weight asphalt
	in.	lbs	lbs	lbs	lbs	lbs
28	0.182	200	60	15.6	22.7	75.7
36	0.160	240	52	45.9	26.0	116.0
40	0.117	152	49	15.3	53.6	34.0
Av.	0.153	197	54	25.6	34.1	75.2

The thickness was checked at various places on the sample with a micrometer which has an anvil head used to measure the thickness of paper. The weights were weighed on a gram scale and converted to pounds. The original sample was first weighed, then the felt which had the bitumen and granules removed by the asphalt extractor was weighed. The granules, those larger than would pass through an 80-mesh sieve and those smaller that passed through an 80-mesh sieve, were then weighed and the difference between the original sample and the sum of the felt and granules was taken as the weight of the bitumen.

There was no analysis of the material in the felt, the quality of the asphalt or the source of material from which the granules were composed. Samples of as many damaged shingles as were possible to obtain were brought into the department. These samples have been marked with a number which correlates with the sample number on the questionnaire filled out at the site of damage. The study of the physical makeup of the damaged asphalt shingles in relationship to their qualities as a roofing product would make a very interesting study.

Nail head withdrawal resistance

A nail head with a 7/16 inch diameter head was drawn through various asphalt shingles with three different patterns, three different thicknesses and at four different temperatures. The data are compiled in Table I and are shown graphically in Figure 11. The average pounds pull for a square butt shingle at 50° F. was 50 pounds, at 88° F. was 27 pounds, at 132° F. was 16 pounds, and at 150° F. was 14 pounds. The thickness of this square butt shingle was 0.171 inches at the place the nail head was pulled through. The two tab hexagonal shingle offered the most resistance to pull. Its thickness was 0.148 inches. A pull of 56 pounds was required at 50° F., 34 pounds at 88° F., 24 pounds at 132° F. and 17 pounds at 150° F. The three tab hexagonal shingle which was 0.137 inches thick offered the least resistance. Forty-five pounds was required at 50° F., 24 pounds at 88° F., 16 pounds at 132° F. and 14 pounds at 150°F.

To obtain the temperature of 50° F., the panels of shingles were placed in a refrigerated room in Botany Hall. The temperatures that were higher than room temperatures, 88° F., were obtained by placing the shingles in the sun.

All shingles were of the same brand. The square butt and the three tab hexagonal shingles were post-war shingles; whereas, the two tab hexagonal shingle was a pre-war shingle.

Tabs were lifted through 4.25 inches at the various temperatures with the same shingles. The data collected are compiled in Table II and shown graphically in Figures 12 and 13. Less pull was required as the temperature increased and more pull was required as the thickness increased, except for the two tab hexagonal shingle which was a pre-war shingle. A square butt shingle of the same bundle with a four inch exposure required about 40 percent more force to lift the tab through 4.25 inches than did a similar square butt asphalt shingle with a five inch exposure.

Tabs of the four types of shingles were bent through 90° until the shingle tab would not resume its original position. These data are shown in Table II and are shown graphically in Figure 13. The square butt shingles at 88°F. required six times as many bends with five inch exposure and eleven times as many bends with four inch exposure than did the other two. The distance across the surface bent was 11 and 11/16 inches for the square butt, 9 inches for the 3 tab hexagonal and 14 inches for the 2 tab hexagonal. An average shingle with temperatures colder or hotter than 88° F. required less bends to cause damage.

Number one red cedar wood shingles with a four inch, a 4.5 inch, and a five inch exposure at 92° F. were pulled over their edge of exposure until broken. The more the exposure the less force was required as is shown in Table III and Figure 19. It required 34.9 pounds per inch width at four inch exposure, 24.2 pounds per inch width at 4.5 inch exposure and 17.8 pounds per inch width at five inch exposure. The thickness of the shingle decreased from

0.315 inch at four inch exposure to 0.307 inch at 4.5 inches exposure and 0.294 inch at five inches exposure. The force required per square foot of area on a wood shingle to tear them off would be 510 pounds, which is much larger than any probable wind force.

Asbestos cement shingles of a multiple unit pattern were broken over their edge of exposure. The exposure was 5.5 inches and the thickness was 0.172 inch. The force required per inch was 1.5 pounds and is shown in Table III. This would mean that a force of 39 pounds per square foot would be required to tear this shingle off a roof. This is also a much greater force than is required to keep the average shingle on a roof. A 50 m.p.h. wind has a force of about 12 pounds per square foot.

DISCUSSION

Good and Damaged Shingles

Location

Owner-operator farms were definitely in the majority in this study in relation to the state average. In the damaged shingle group, the preponderance was not nearly as great as in the good shingles. Whether it would change the significance of this study if a close parallelism of the state average were followed, the author could not say. The objective was to find good and damaged shingles and to obtain complete data on these shingles. As the important part of this study was to find what constitutes a good and a poor shingle, it is believed these results were obtained.

Protection for an asphalt shingle roof was found very important. Good asphalt shingles had protection 86 percent of the time, whereas damaged asphalt shingles had protection but 43 percent of the time. The damaged asphalt shingles had no protection 57 percent of the time and the good asphalt shingles had no protection 14 percent of the time. Trees, hills and other buildings can cause wind to be less severe on a roof and can protect the roof from the full blast of the wind which might catch the tabs. Trees which shade a roof were a definite asset in that they decrease the amount of sun on the roof. If wind cannot blow an asphalt shingle off a roof, the sun is the factor which alone can wear out a roof. Examples of this are shown in Figures 21 and 22. Shingles that have had protection from the sun by trees or by having a northern exposure do not wear out to any degree, even after 30 years of service.

The desire of all users of asphalt shingles is that the asphalt shingle roof would have a life expectancy as great as the dwelling to which the shingle was applied. As it is believed that the sun is the factor that causes an asphalt shingle to wear out, it is also believed that the shingle should be protected from the sun. Bitumen evaporates from a shingle due to high temperatures caused by direct sun rays. Temperatures on an asphalt shingle roof upon the same day with the same air temperature varied 60 degrees depending on whether the sun was shining or was under the clouds. It would be impossible to have all roofs shaded by trees, but it might be possible that a dressing could be developed that would cause the bitumen of an asphalt shingle to be sealed in so that the heat of the sun could not cause the bitumen to evaporate. It should also reflect the sun rays so that the heat on an asphalt roof would approach air temperature. This dressing could be used in new applications and in prolonging the life of old asphalt shingle roofs.

There is felt that little can be done about the direction of exposure of roofs or the direction from which the wind blows and needs no discussion here.

The location of the damage was highest in the center of the roof. The center of the roof comprises about 60 percent of the area of a roof and had about 60 percent of the damage. The different areas on a roof gave troubles for various reasons.

The center area probably had more careless workmanship than any other part, as this was the area where an asphalt strip shingle could be more rapidly applied than anywhere else. The sides and bottoms often had a poor or rotten deck on which to nail in instances where it was a reroofing job. Rake strips are always recommended in reroofing whenever an old roof is being covered by a new roof. The top was found to fail a number of times due to the lack of the use of one more course of shingles. In order to avoid cutting shingles a very wide exposure was left here.

No one group of individuals can be blamed or given credit for poor or good application. Carpenters applied 86 percent of the damaged shingles and 93 percent of the good asphalt shingles. Contractors applied 5 percent of those failing, and applied no good shingles. The person who applies an asphalt shingle is more responsible for its serviceability to a greater extent than any other factor.

Shingles can be and have been applied by nearly everyone. Careful workmen that follow instructions implicitly are necessary if good construction is to follow. It is believed that good workmanship with more complete and proper instructions than are now offered can give much impetus to the use and the life expectancy of asphalt shingle roofs.

Building characteristics

The two largest buildings on most farms are the barn and the house. These two accounted for 96 percent and 80 percent of the good and damaged asphalt shingles, respectively. These two buildings are more highly exposed to the wind and the sun, which accounts for most of the damage, than are the other types of buildings on the farm. However, it is believed that the barn and house have the better construction of the two groups. It is not necessary to have more good or damaged asphalt shingles in one group than the other if proper construction and good workmanship are used.

Losses to a curved roof of the round or gothic style were nearly 0 percent, whereas, roofs with the gable, gambrel, hip, etc., style had 99 percent of the losses. The total percent of gothic or round roofs in Iowa is not known but it is relatively small. In actuality, a curved roof should give more trouble than a flat roof as this type of roof causes the butts of the shingles to lift away from the roof if the shingle maintained its original position. Many such roofs have their tabs nailed down with a small shingle nail as is shown in Figure 23. This procedure is not recommended as it offers a direct passageway for rain through the roof. It is believed by the author that the shape of a roof is not a cause of failure.

The use of starter strips and roofers felt was not very prominent as only 6 percent had starter strips and 10 percent had roofers felt in good asphalt shingles. None used a starter strip and 8 percent used a roofers felt in damaged asphalt shingles. A starter strip is of value in that it gives more protection to that part of the roof that has the greatest amount of water passing over it. In many instances a course of wood shingles was used in lieu of a starter strip. This has caused considerable trouble due to the fact that with water tending to follow back on the wood shingles and then drip off, a good deal of rotting has taken place. A metal strip, that is non-corrosive, as recommended by the Asphalt Roofing Industry Bureau would be advantageous to eliminate rotting. Many people have used an asphalt strip shingle reversed with no starter strip, but it is believed that both could be used to an advantage.

Roofers felt has been recommended to keep dampness off a roof and to keep wind from being able to pass through a deck readily. As far as this study is concerned there was no evidence that a roofers felt was of any advantage. The use of the roofers felt cannot be recommended as any help and likewise it cannot be recommended as being of any harm.

Shingle characteristics

The correct type of an asphalt shingle is causing a good deal of controversy in the asphalt roofing industry today. There are various patterns such as are shown in Figures 21, 28, 56, 57 and 58. The two most common are square butt and hexagonal, about 90 percent of the total in Iowa. All shingles have one thing in common--they cover the same area per square. Each individual shingle has different amounts of area exposed per strip and different areas exposed per tab. A three tab square butt shingle with five inch exposure has an area of 58.1 square inches per distance bent, the width across the tab at the edge of exposure which is 11 and 5/8 inches, or a ratio of 5 to 1. A three tab hexagonal shingle has an area of 27.45 square inches to a distance bent of 9.5 inches, or a ratio of 2.9 to 1. A two tab hexagonal shingle has an area of 41.6 square inches to a distance bent of 12.5 inches with a ratio of 3.3 to 1. A two tab thatch type shingle as shown in Figure 57 has an area of 36.2 square inches to a distance bent of 18 inches with a ratio of 2 to 1. A square butt shingle with four inch exposure has an area of 46.5 square inches to a distance bent of 11 and 5/8 inches or a ratio of 4 to 1.

It is evident that the lower the ratio, the more wind resistant is a tab. This point was brought out by many lumber dealers and insurance agents as a reason for the use of the thatch type and three tab hexagonal shingle. There were five losses of the three tab hexagonal pattern but as no record was kept between three tab and two tab hexagonal shingles for the total percent in the state, it is not possible to say whether the three tab hexagonal asphalt shingle has a definite advantage over the two tab hexagonal shingle. Only one loss occurred in the thatch type and this shingle failed due to nail heads pulling through. Also, no data were collected as tc what percent of the roofs have this type shingle. However, the thatch type has been recommended by many lumber dealers due to the fact that they have had little trouble with it, and that it is a very economical shingle, costing about the same as a hexagonal.

Other types of shingles such as the thatch type, tee-lock, interlocking, individual and various other patterns had a higher percentage of losses in ratio to the total number on roofs than did either the square butt or hexagonal. Conversely they had a higher percentage of good asphalt shingles than the total percentage of this type of shingle in Iowa. There were a number of failures of tee-lock shingles as shown in Figure 66, due to the weakening of the interlocking tabs. This type of shingle has been discontinued by the manufacturers but is being sold in similar patterns such as the tite-on or weather master.

The tite-on shingle has given good service as a whole and is being recommended for use in the country by many insurance agents and lumber dealers. The shingle has been advertised as withstanding hurricanes and that it was practically impossible to blow off; however, there were two instances of failure found. These failures are shown in Figure 63 and Figure 64. The one with the shingles blown off occurred when the roof was twelve years old and the other was blown off and repaired when ten years old. The advantage of this type shingle is that it will withstand much more wind than the more conventional patterns as they are now fastened. The disadvantages are the appearance, the difficulty of repair when damaged, and the dislike of many carpenters to apply it.

The average age of the damaged shingles was seven years while the average age of the good shingles was 22 years. This average age of the damaged shingles was one year less than that found by Esmay (3). Esmay's study covered but one year, 1946, and the author's study covered part of 1947 and 1948. Perhaps neither age would be correct over a greater period of years. The significant point is that this period of use of the asphalt shingle that was damaged was too short in comparison to the service that the good shingles have given. This is the crux of the whole study--to find a way

Fig. 63. A Tite-on
Shingle Failure

Fig. 64. A Tite-on Shingle
Failure and Repair

Fig. 65. Too High Nailing

Fig. 66. A Tee-Lock
Shingle Failure

for all asphalt shingles to be in good condition after 22 years of service as the good ones were found. The way to increase this life expectancy will be discussed fully further in this study.

The good shingles were 0.016 inch thicker than the damaged shingles. This does not seem much, but it is 10 percent greater. It must also be taken into consideration that the good shingles were on an average 15 years older than the damaged shingles; for shingles get thinner with age. Thickness is important as it gives greater stiffness, more ability to withstand wind, and more bitumen to be evaporated which will prolong the life of the shingle.

Only square butt and hexagonal shingles were used whenever the amount exposed to the weather was considered. The good shingles were exposed 0.63 of an inch less than the damaged shingles. If the tab is considered as a cantilever beam with a uniform load such as a wind would offer, the moment varies as the square of the distance. With this in mind it is seen that the damaged shingles would have 1.3 more moment than the good shingles if the cantilever is considered at the edge of exposure only.

The distance that the nails are from the edge of exposure is more nearly the position at which the cantilever can be considered fastened. The good asphalt shingles had an average distance of 5.33 inches and the damaged asphalt shingles had an average distance of 6.12 inches, which means that there is 1.32 times more moment. The moment under either circumstances is in about the same ratio as the average shingle would be as applied, but in many cases shingles were observed that were nailed at 8 inches instead of 5 and 5/8 inches as is recommended. Under these circumstances the moment is 2.02 times as great for the eight inch distance of nailing than it would be for 5 and 5/8 inches as recommended. This is evident proof why careful installation is so necessary. Too high nailing is shown in Figure 65.

A greater number of plys of coverage will give protection only if the outer layer is damaged, but will not give any more years service than less number of plys of coverage if not damaged; as only the exposed surface wears out. When it is acknowledged that the roof should be designed so that the shingles cannot be blown off, it must also be acknowledged that more than one ply coverage is not necessary, except where it is needed to have a means of fastening the strip shingle down. Therefore, even though it is shown by this study that the good shingles had more plys coverage on an average than did the damaged shingles, it is not proof that a three ply roof should give more service than a one ply roof. It was shown that 13 percent of the good roofs had but one ply coverage and this is further evidence that only the shingle surface exposed wears out.

All but one roof of both good and damaged shingles were fastened with galvanized nails. Nail heads vary in size from 5/16 of an inch to 5/8 of an inch D. There were a number of failures due to the reason that too small nail heads were used. The nail head should be at least 7/16 of an inch D and preferably larger, or there is a risk that the asphalt shingle will pull out over the nail head. Figure 70 shows an example of a too small nail head causing failure.

The one shingle that failed that was cemented as well as fastened with a nail is shown in Figure 67. Cementing is not a cure-all if care is not taken in application. In this instance the tab did not come into contact with the shingle below before the cement dried. Cement is applied in most instances after the roof has been applied and if the day is not rather warm, the tabs do not settle down and seal but remain curved and the cement is allowed to dry. Cement should be applied on a clear day with an air temperature of around 75° F. If the day is cloudy the roof temperature will approach air temperature and will not be hot enough to cause good sealing of the two tabs. It is also preferable that the cement be applied as the roof is applied. The cement should be applied to the shingle that is already nailed, just above or on the nail heads for either square butt or

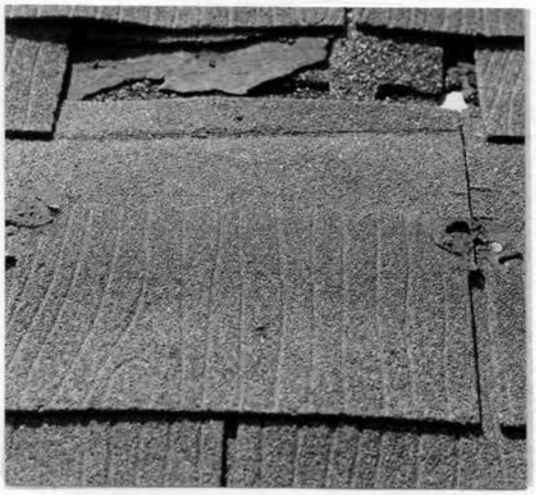


Fig. 67. Careless Cementing

Fig. 68. A Two Year Old Clipped Roof

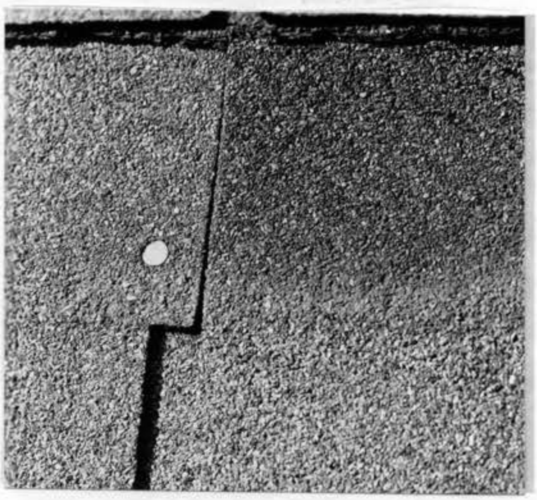


Fig. 69. An Inadequate Number of Nails

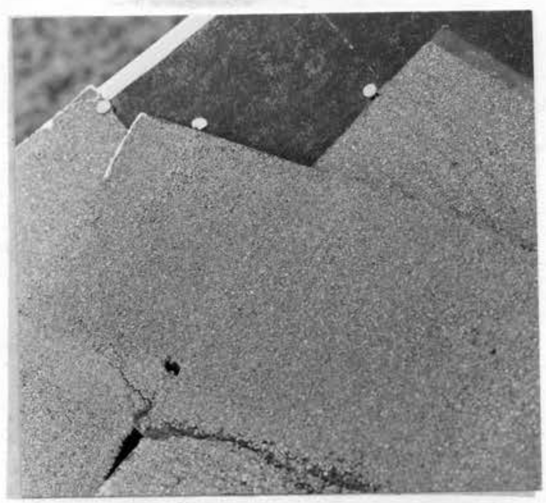


Fig. 70. Use of a Too Small Nail Head

hexagonal asphalt shingles as is shown in Figures 47 and 48. A putty knife or a caulking gun is most commonly used, but a gun that could be designed much like a grease gun to allow just the proper amount of asphalt per stroke would be preferable. A properly cemented-down asphalt shingle will last until the sun wears out the shingle and this method of application is highly recommended by the author for either new construction or repair work.

Clips have been another means of fastening tabs down so that wind cannot blow them away. Figures 68 and 29 show two different shingles that have been clipped. Figure 68 has been clipped for one year and Figure 29 has been clipped for ten years. The clip can be used equally well on either a square butt or a hexagonal asphalt shingle. All roofs that have been examined have given excellent service. This type clip does not cut the asphalt shingle through as does a staple. There is no evidence of damage to the tab as shown in Figure 29. For either new construction or repair work this type of fastener is also recommended by the author.

Repair work of asphalt shingles is a large item to Iowa farmers every year. Approximately one percent of all farmsteads in Iowa had damage for 1946. Many people who were visited in this study were considerably perturbed as to how a damaged roof could be repaired. All damaged shingles should be replaced by new ones. New shingles should be kept on hand from the first installation and the author recommends that a bundle be stored for any such emergency as many people have discovered the patterns and colors that they originally applied cannot be purchased. It is easily conceivable that many unsightly roofs are due to these circumstances. The most common patterns and colors are the most practical to use. After the shingles have been replaced it is recommended that the entire roof be either cemented or clipped down in order that damage from wind will not occur again.

As the old saying goes, that for the loss of a nail the battle was lost, it also goes without saying that many an asphalt shingle was lost for the same reason. Figure 69 shows an example of this. Nails applied at the time of installation are relatively cheap in comparison to the installation of them after the shingle has been damaged. The good shingles had 221 more nails per square on an average than did the damaged shingles. The cost of these nails would be approximately $2.25 for an average roof. Labor would amount to about $0.75 more with a total cost of about $3.00 per roof area. Care should also be taken to see that the nails are long enough so that the penetration of the roof deck is great enough to hold the nail securely. It is recommended by the author that six nails be used on the square butt asphalt shingle as is shown in Figure 47. Six nails per strip should be used in the thatch type as is shown in Figure 49 if cement is not used. The placement of the nail is important and it is recommended that the position of nailing as shown in Figures47, 48 and 49 be closely approximated.

The roof deck is very important to the life expectancy of an asphalt shingle. In the first place a good deck is necessary in order that the nails have a firm hold. Figure 74 shows an old wood deck that did not offer this need and failure occurred due to nails pulling out. Another important reason for a proper deck is hail damage. Hail will damage any asphalt shingle that does not have a perfectly smooth surfaced deck under it. Figure 71 shows hail damage to an asphalt shingle, whereas, Figure 72 shows no damage, and yet the two roofs were within 100 feet of each other when hit by hail. Figure 73 shows how the farmer was replacing a barn roof after this all too realistic lesson happened to him. This roof is a good example and is recommended as the way to replace an old wood shingle roof. It is recommended that the old wood shingles be removed, the deck rebuilt so that there are no cracks, knotholes or any cause for a gap to be left below the asphalt shingle which can be punctured if hail occurs. Many roof decks have been built with the idea in mind that a tight deck was being made but due to the use of cracked, poorly matched or knotty lumber, a good

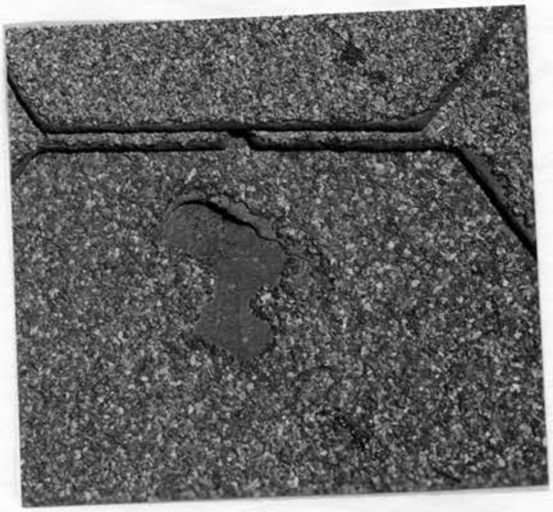


Fig. 71. Hail Damage Over
Wood Shingles

Fig. 72. No Hail Damage Over
a Smooth, Tight Deck

Fig. 73. Proper Method of
Replacing Wood Shingles
with Asphalt

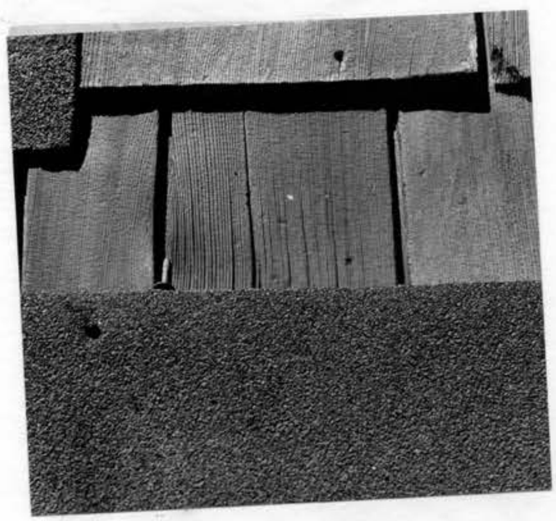


Fig. 74. A Poor Deck

deck was not obtained. If green lumber is used, damage as shown in Figure 76 can and will happen. Whenever two nails in the same shingle are placed on the same board, a bulging effect takes place as is shown and whenever two nails are placed in the same shingle on two different boards, the shingle is torn and damage such as shown in Figure 76 occurs.

It is recommended that a closely matched deck be constructed of tongue and groove lumber under any asphalt shingle. This is done so that hail damage cannot occur and so that nails have a secure member to be fastened to in order that they will not pull out when wind pressure is exerted on an asphalt shingle tab. In repair work old wood shingles should be removed and the deck replaced as shown in Figure 73. Any old asphalt shingles or roll roofing should also be removed. It has been recommended by many people that this old material offers insulation and a protection for the new roof, but the disadvantages offset the advantages of removing the old material. It will be necessary to use a tarpaulin on a house to protect the contents against damage with this type of replacement with asphalt shingles. To eliminate this cost of removal of the old roof, a material is needed that could be spread over the old shingles whether wood or asphalt to give a smooth flat surface. This material must not be too hard or too soft, and must be economical and easy to apply.

Fig. 75. Shingle Blowing Up on a Windy Day

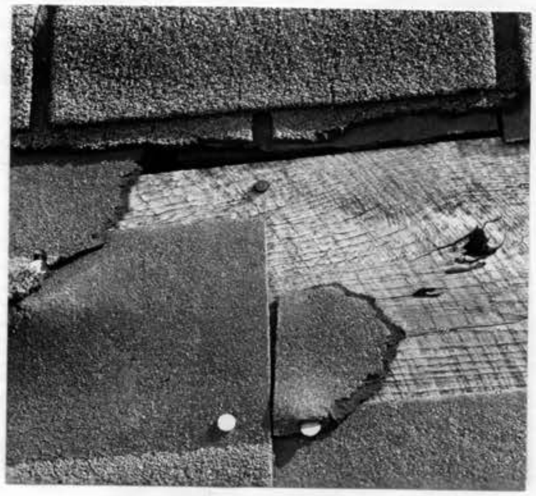


Fig. 76. Green Sheathing

Fig. 77. Shingles Blowing up on a Windy Day

Fig. 78. Shingles Blowing and Later Found Damaged

The age of the deck to which the asphalt shingles were nailed was 26.7 years for the damaged and 28 years for the good asphalt shingles. This is of little importance except that the age of the old wood shingles was determined. The average age of wood shingles when replaced with asphalt shingles for the good asphalt shingles was 27 years for houses, 29 years for all others, 28 years for all and the average age for the damaged asphalt shingles was 28.6 years for houses, 37.3 years for all other and 31 years for all wood shingle roofs.

The self-sealing of asphalt shingles is highly desirable but this condition was found in only three out of 120 damaged roofs. In these three cases, the roof was not completely sealed and that was where the damage occurred. The evidence that sealing is desirable can be seen when 13 out of 29 good asphalt shingle roofs were found in this condition. As self-sealing has little assurance of taking place, it is again recommended that this condition be assimilated simulated by a cement, which has been developed by a number of asphalt shingle manufacturers, placed under each tab or by a clip used on each tab.

Nails that are not driven perpendicular to a shingle cause a cutting of the shingle to take place. This is shown in Figure 30. Tests in the laboratory showed that it required 12 pounds to pull a nail through an asphalt shingle at 60°, whereas it required 30 pounds to pull it through when a nail was perpendicular to the shingle. With continuous motion of a tab by the wind as is shown in Figures 75 and 77 it would undoubtedly take much less force to cause the nail to pull through.

Examples as are shown in Figures 75 and 77 are not uncommon in Iowa whenever the wind is blowing strongly. This is not a good advertisement for the use of asphalt shingles and should be corrected by having all tabs either cemented or clipped. Figure 78 shows asphalt shingles that were blowing up in April and when examined in May the tabs were blown off the roof. This again shows the need of having the tabs cemented or clipped.

The resistance offered by an asphalt shingle tab to lifting is not very great. An average of 1.58 pounds was required to lift the damaged shingles and 2.36 pounds for the good shingles through 4.25 inches. The average square butt shingle tab has about 58 square inches of surface area, which means that it would require about 3.9 pounds per square foot pressure to lift an average damaged shingle and about 5.75 pounds pressure per square foot to lift an average good shingle. For the average three tab hexagonal shingle the area is 27.5 square inches and it would require about 4.1 pounds pressure per square foot to lift an average damaged shingle. There were no good three tab hexagonal asphalt shingles.

With the use of the experimental formula,

$$P = 0.004V^2$$

and the straight line formula,

$$Pn = \frac{A \times P}{45}$$

the velocity of wind can be determined that would have caused the tabs to lift. The experimental and the straight line formulas are not to be considered as giving the correct results. They are used to show the relative resistance to wind velocity between various patterns of asphalt shingles. The average damaged and good square butt asphalt shingles would have resisted a wind velocity up to 28.6 and 32.7 m.p.h. The average damaged three tab hexagonal asphalt shingle which had an average resistance of 0.75 pounds would have resisted a wind velocity up to 25 m.p.h. There were no good three tab hexagonal asphalt shingles.

The data collected in the laboratory on pounds pull to lift a tab 4.25 inches would have given a velocity from a minimum of 6.7 m.p.h. for a square butt asphalt shingle at 150° F. to a maximum of 67 m.p.h. for a two tab hexagonal asphalt shingle at 50° F. It is definitely a fact that high temperatures on a roof cause asphalt shingle tabs to have little resistance to wind. Hexagonal shingles also offer much more resistance to wind than does a square butt asphalt shingle, according to this theory of the experimental and the straight line formula.

The temperature on the roof was on an average 28° F. higher than air temperature for damaged shingles and 26° F. higher than air temperature for good asphalt shingles. Temperatures on an asphalt shingle roof get considerably higher than air temperature. When the air temperature was 100° F., the temperature on an asphalt roof, 167° F.; on a corrugated aluminum roof, 127° F.; and on a wood shingle roof, 147° F. The temperature directly below the roof was 120° F. for asphalt, 108° F. for the aluminum and 110° F. for the wood shingles. When the air temperature was 84° F., the roof temperature for asphalt was 130° F.; aluminum was 113° F.; asbestos cement, 111° F.; and corrugated steel (4), 129° F. Asphalt shingles will cause more heat to be collected on a roof than any other type roofing and as a roof will cause much more heat in a building than any other type roofing. This factor of high heat absorption is a disadvantage and improvement is needed to lower the roof temperature closer to air temperature.

Failure

Numerous causes of failures have been discussed already but the complete breakdown of failures is as follows: (a) nails pulled through, 6 percent; (b) nails pulled out, 4 percent; (c) broken, 81 percent; (d) other, 9 percent. The most prevalent cause of failure was that the tab broke. Again this is more conclusive proof that a means of fastening the tab down in a manner such as cement or clips is very necessary. A typical example of breaking is shown in Figure 80. Figure 70 shows a shingle that pulled through the nail head and Figure 74 shows a shingle that failed due to the fact that the nails pulled out when the deck was so poor that the nail could not be securely fastened. Failures noted as "other",which make up 9 percent of the losses in this study and made up 18.5 percent of losses for 1946, were hail losses.

There were twelve different asphalt shingle roofs inspected for hail loss. Figures 71 and 79 show typical cases of hail damage. Figure 79 is an example of an asphalt shingle hit 13 years ago and Figure 71 is an example of an asphalt shingle hit two weeks prior to the time the picture was taken. The cause for failure, any deck that is not perfectly smooth, has been discussed. It is definitely believed that hail will do no material damage to an asphalt shingle except for knocking a few granules loose. This will not hurt the water turning ability of the shingle at all, as is shown in the upper left part of the picture in Figure 79, which was damaged by hail 13 years ago. However, it does spoil the original appearance of the roof and for only the damage to the appearance and the cost of a dressing should the insurance companies pay. A dressing that helps seal the bitumen in should be used. Various other kinds

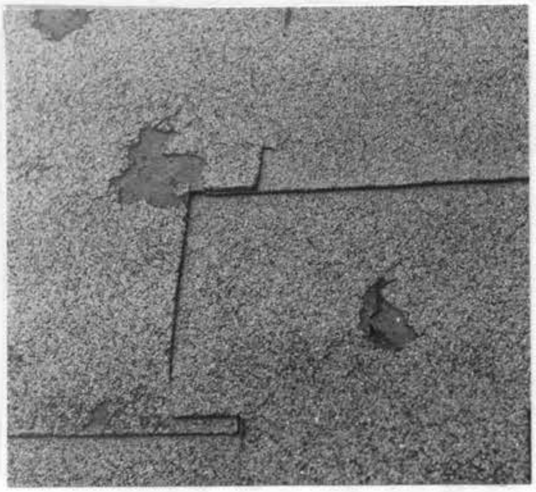


Fig. 79. Hail Damage of 13 Years

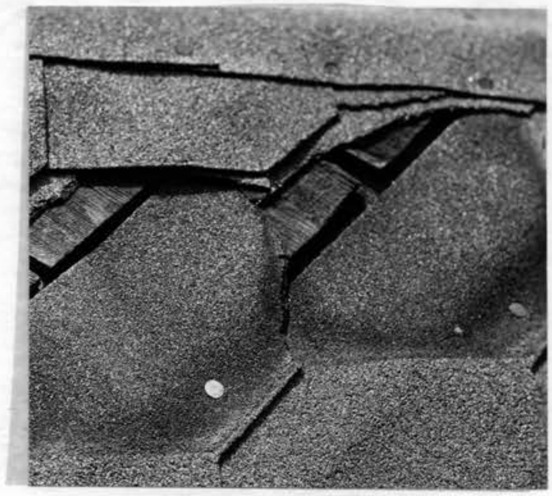


Fig. 80. A Typical Failure by Breaking

Fig. 81. Cemented Down and No Bulge at 135° F.

Fig. 82. Cemented Down and No Bulge at 135° F.

of roofs were inspected for hail damage in the area where hail hit and wood, asbestos cement, slate and tile roofs were damaged. The hexagonal pattern asbestos cement shingles were damaged while the American and multiple unit patterns were not.

The average amount of damage per roof was 9.9 percent. This small percentage can be explained in part by the fact that wind pressures are not uniform over a roof area and that the large percentage of failures was due to poor application. In nearly all instances poor workmanship was not prevalent over the entire roof area and this caused losses to be localized on the roof. This condition was also shown by the fact that in 87 percent of losses the damage was to spots and only 13 percent of damage was to one area.

Previous claims occurred in 28 percent of the cases in a period of but 0.63 year prior to the second loss. This is generally caused by poor repair work due to carelessness and to the lack of information on how to repair a roof. Roofs should be carefully inspected over the entire area to eliminate the probability of more damage. The manner in which a roof should be repaired has been discussed prior to this part under "shingle characteristics".

Insurance agents and lumber dealers

The opinions of lumber dealers and insurance agents substantiate to a degree the findings of the author in this study. They believe that too few nails, tabs not cemented down and too high nailing were the causes of most failures. Proper nailing and cementing or clipping the tabs is necessary if the asphalt shingles are to resist wind.

The large majority of lumber dealers and insurance agents believed that weight was a factor in helping keep asphalt shingles from being blown away by wind. With the conventional manner of application this is true as was shown in the study that the good asphalt shingles were 10 percent thicker. Thickness is generally a criterion of the total weight. However, it is believed by the author that a light weight shingle per square but not weight per square inch of material can be made to give as good and long service as the heavier weight shingle per square, by either cementing or clipping. By this, it is meant that a shingle with the same thickness but less total plys of coverage will last as long as a similar thick shingle with more plys of coverage; for the sun is the factor that causes a shingle to wear out if the tabs are securely fastened.

An even decision was drawn as to the use of four inch or five inch exposure on a square butt shingle. Those that advocated four inch exposure did so with the belief that they were more wind resistant. This is shown as being true in the work done in the laboratory. A four inch exposed shingle would withstand a wind of 3 m.p.h. more velocity for the different temperatures and would withstand 93 percent more bends through 90° than would a five inch exposed shingle. The use of clips or cement would eliminate the necessity of the four inch exposure with its added 25 percent cost and require only the five inch exposure. The use of clips or cement would also eliminate the need of an asphalt shingle bending through 90° and it would make little difference as to how many times various kinds of shingles could bend before permanent damage took place.

Most lumber dealers thought that a roofers felt was necessary and that a starter strip was not. This cannot be substantiated by this study. Perhaps the desire to sell material, of which roofers felt is a much larger item than a starter strip, has something to do with it. However, in nearly all cases the lumber dealer was serious in his belief that the use of a roofers felt was needed.

The use of clips and cement and the recommendation of the use of clips and cement were believed as the correct methods of application in the majority of the cases. The author agrees heartily with this belief and this study shows the need of clips or cement to keep the tabs tightly fastened to the roof.

Without the use of clips, weather is a factor in installing shingles. Of course, it must be understood that when a roof gets too hot, over 140° F., no application should take place as the roof will be scuffed and damaged. If weather is too cold, the shingle will not form itself well to a roof and if cement were to be used, a good sealing effect would not take place. Clips, however, could be used to a much better advantage than cement in cold weather, less than 60° F., air temperature. Application on a clear day when there is little wind and a temperature of about 75° F. is preferable for any manner of application.

Interlocking shingles have been used for at least 15 years. There seems to be rather diverse opinions as to their use. Fifty-five percent of the lumber dealers have used them and only 47 percent recommended their use. Insurance agents recommended them highly, with 90 percent doing so. The old tee-lock shingle, as shown in Figure 66, has given but mediocre service. The type of interlocking shingle as shown in Figure 58 has likewise given but fair service. Lack of enough nails, too little coverage, the weakening of the tabs that interlock, and the fact that no interlocking shingle is interlocking around the outside edges has been the cause of failure in most instances. A pattern, the tite-on, has come into prominent use in the last few years. This type of shingle, as a whole, has given very good service with but two losses found over the state. This type shingle also fails due to the fact that it is not interlocking at the exposed edges. However, if the conventional patterns, hexagonal or square butt, are not cemented or clipped, the tite-on would be recommended for use first.

It would be very desirable that shingles would seal and about 60 percent of the lumber dealers and insurance agents have seen them do so. There was a doubt in the author's mind if sealing would take place and this was the reason for asking this question. This doubt has been cleared as a number of roofs examined were found sealed down by the action of the sun, but this is found in a small percentage (about one percent) of the roofs.

Advantages and Disadvantages of Common Roofing Material

Asphalt shingles

Advantages.

1. Low first cost
2. Ease of application
3. Good appearing roof
4. Damage easily repaired
5. Fire resistant
6. Hail resistant on proper deck
7. Light weight on roof

Disadvantages.

1. High amount of damage by wind
2. High maintenance costs
3. Undesirable appearance when weathered or damaged
4. Low life expectancy
5. High heat absorptivity

Wood shingles

Advantages.

1. Highly wind resistant
2. Good hail resistance
3. Average life expectancy
4. Light weight on roof
5. Ease of application
6. A low cost roof deck
7. Low heat absorptivity

Disadvantages.

1. Not fire resistant
2. High original cost
3. Poor appearance when weathered
4. Difficulty in repairing when damaged
5. Discriminated against by fire insurance companies

Asbestos cement shingles

Advantages.

1. Highly wind resistant
2. Fire proof
3. Long life expectancy
4. Hail resistant
5. Good appearance
6. Low heat absorptivity

Disadvantages.

1. High original cost
2. Heavy weight on roof
3. Difficulty in avoiding breakage in application
4. Difficulty in avoiding breakage in repair

Aluminum

Advantages.

1. Fire proof
2. Light weight on roof
3. Low heat absorptivity
4. Long life
5. Ease of application
6. Low cost of deck

Disadvantages.

1. Appearance
2. Average original cost

3. Wind resistant qualities undetermined

4. Hail resistant qualities undetermined

Steel

Advantages.

1. Fire proof

2. Light weight on roof

3. Ease of application

4. Low cost of deck

5. Low first cost

Disadvantages.

1. Appearance

2. Wind resistance

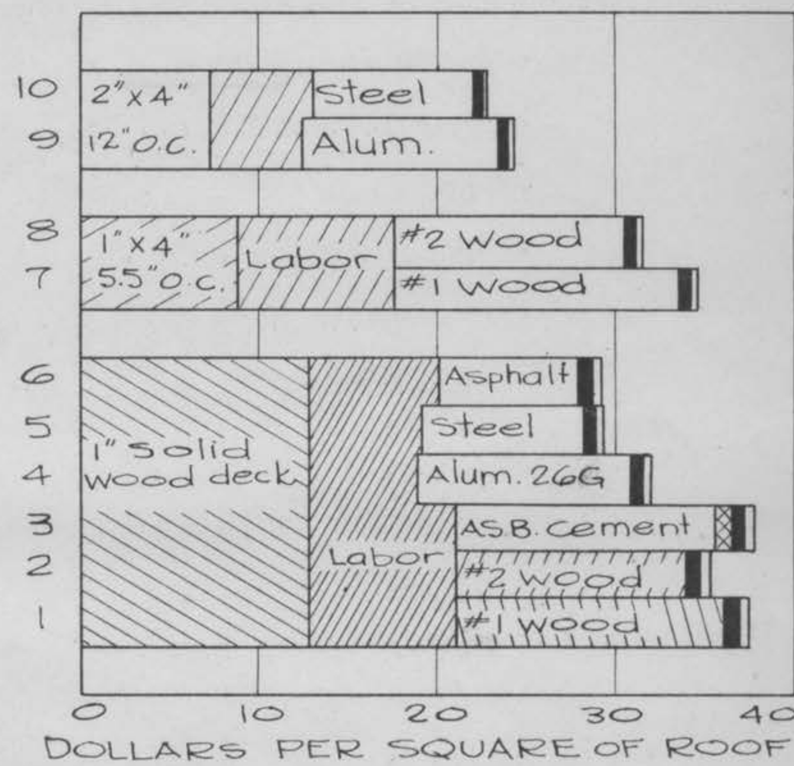
3. Average life expectancy

Cost Studies of Various Roofing Materials

Material and labor costs fluctuate from one point in Iowa to another. An average value will be set on these costs. The costs of various roofs per square and a breakdown of the costs as shown in Figure 83 are as follows: Dale (2) computed labor, deck material and nail costs.

1. No. 1 wood shingles over a solid deck

1" solid roof deck	$12.90
Labor	8.30
Wood shingles	15.00
Roofing nails	0.45
Sheathing nails	0.35
	$37.00



■ Roofing Nails

□ Sheathing Nails

⊠ #15 Roofers Felt

FIG. 55. ROOFING COSTS

2. No. 2 wood shingles over a solid deck

1" solid roof deck	$12.90
Labor	8.30
Wood shingles	13.00
Roofing nails	0.45
Sheathing nails	0.35
Total	$35.00

3. Asbestos cement shingles over a solid deck

1" solid roof deck	$12.90
Labor	8.30
Shingles	14.50
Felt	1.00
Roofing nails	0.45
Sheathing nails	0.35
Total	$37.50

4. Aluminum, 26 gauge, over a solid deck

1" solid roof deck	$12.90
Labor	6.00
Aluminum	11.00
Roofing nails	0.45
Sheathing nails	0.35
Total	$30.70

5. Corrugated steel over a solid deck

1" solid roof deck	$12.90
Labor	6.40
Steel, 26 gauge	9.00
Roofing nails	0.45
Sheathing nails	0.35
Total	$29.10

6. Asphalt shingles over a solid deck

1" solid roof deck	$12.90
Labor	7.30
Shingles	7.80
Starter strip and metal strip	0.20
Roofing nails	0.45
Sheathing nails	0.35
Total	$29.00

7. No. 1 wood shingles over 1" x 4", 5.5" on center

Deck	$ 8.90
Labor	8.75
Shingles	15.00
Roofing nails	0.45
Sheathing nails	0.30
Total	$33.40

8. No. 2 wood shingles over 1" x 4", 5.5" on center

Deck	$ 8.90
Labor	8.75
Shingles	13.00
Roofing nails	0.45
Sheathing nails	0.30
Total	$31.40

9. 26 gauge aluminum over 2" x 4", 12" on center

Deck	$ 7.30
Labor	5.25
Aluminum	11.00
Roofing nails	0.40
Sheathing nails	0.35
Total	$24.30

10. 26 gauge steel over 2" x 4", 12" on center

Deck	$ 7.30
Labor	5.75
Steel	9.00
Roofing nails	0.40
Sheathing nails	0.35
Total	$22.80

In these different roofs numbers 3, 6, 7, 8, 9 and 10 will be discussed. These roofs are the only ones that are considered practical in everyday construction. Numbers 1 and 2 need not be placed over a tight deck and numbers 4 and 5 can be placed over a tight deck if maximum wind protection is desired, but it is not practical or recommended.

The most expensive type of roof is an asbestos cement roof. This roof would have a total cost of $37.50. It offers the longest service of probably any of the roofs, the best appearing roof and fireproof. For house construction, barns, garages and any other long life type structures, it is believed by the author as the best type construction that is offered the Iowa farmer.

Number one red cedar wood shingles on 1" x 4", 5.5" on center, is the second most expensive roof today. This roof would cost $33.40. This type roof offers a service of about 30 years, high wind resistance and a good pattern for farm buildings. For the average farm building, this type of roof is the second best type of construction. Number two red cedar wood shingles on 1" x 4", 5.5" on center, will offer nearly as good a roof as the number one wood shingles and would be picked as the third best roof.

Asphalt shingles with a cost of $29.00, which when properly applied, gives a roof of esthetic value, fire resistance and economy. This type of roof would be placed in fourth place in the choice of roofs for an average farm building in Iowa. However, if a thick asphalt shingle of any leading manufacturer, either cemented or clipped down, were used, it could be placed equal to a number one wood shingle.

Aluminum over 2" x 4", 12" on center, is a new type of roof that gives long service if wind does not damage it, rather poor appearance, fire proofness and economy. This type of roof would be placed in fifth place by the author in choice of roofs for an average Iowa farm building as not enough use has been made of it to know how it will serve.

Corrugated steel over 2" x 4", 12" on center, has been used on Iowa farm buildings for many years. This type of roofing is economical, fire proof, will corrode, and is not very wind resistant. In the author's opinion this type roof should be placed in sixth place for use on an average Iowa farm building.

These roofs and the breakdown of costs of labor and material are shown graphically in Figure 83.

Cost Studies of Various Asphalt Shingle Roofs

The costs of material and labor were obtained from lumber dealers in various parts of the state. Felt is not believed necessary, whereas a starter strip and a metal edge strip are. The cost of a starter strip and a metal edge strip is figured for an average sized building and would amount to about $1.00 for material and labor.

1. 5 inch exposure square butt, 4 nails

Shingles	$ 8.25
Labor	4.00
Nails	0.45
Starter strip	1.00
Total	$13.70

2. 5 inch exposure square butt, 6 nails

Shingles	$ 8.25
Labor	4.50
Nails	0.70
Starter strip	1.00
Total	$14.45

3. 4 inch exposure square butt, 4 nails

Shingles	$10.30
Labor	5.00
Nails	0.55
Starter strip	1.00
Total	$16.85

4. 4 inch exposure square butt, 6 nails

Shingles	$10.30
Labor	5.50
Nails	0.85
Starter strip	1.00
Total	$17.65

5. 5 inch exposure square butt, 4 nails and clips

Shingles	$ 8.25
Labor	4.55
Nails	0.45
Starter strip	1.00
Clips	0.55
Total	$14.80

6. 5 inch exposure square butt, 6 nails and clips

Shingles	$ 8.25
Labor	5.05
Nails	0.70
Starter strip	1.00
Clips	0.55
Total	$15.55

7. 5 inch exposure square butt, 4 nails and cement

Shingles	$ 8.25
Labor	4.90
Nails	0.45
Starter strip	1.00
Cement	0.65
Total	$15.25

8. 5 inch exposure square butt, 6 nails and cement

Shingles	$ 8.25
Labor	5.40
Nails	0.70
Starter strip	1.00
Cement	0.65
Total	$16.00

8. Hexagonal, 4 nails

Shingles	$ 7.00
Labor	4.25
Nails	0.50
Starter strip	1.00
Total	$12.75

10. Hexagonal, 6 nails

Shingles	$ 7.00
Labor	4.75
Nails	0.75
Starter strip	1.00
Total	$13.50

11. Hexagonal, 4 nails and clip

Shingles	$ 7.00
Labor	4.85
Nails	0.50
Starter strip	1.00
Clip	0.60
Total	$13.95

12. Hexagonal, 4 nails and cement

Shingles	$ 7.00
Labor	5.20
Nails	0.50
Starter strip	1.00
Cement	0.65
Total	$14.35

13. Thatch type, 3 nails and cement

Shingles	$ 6.50
Labor	5.00
Nails	0.40
Starter strip	1.00
Cement	0.40
Total	$13.30

14. Thatch type, 6 nails

Shingles	$ 6.50
Labor	4.75
Nails	0.75
Starter strip	1.00
Total	$13.00

15. Tite-on, double coverage

Shingles	$ 9.25
Labor	5.25
Nails	0.40
Starter strip	1.00
Total	$15.90

16. Tite-on, single coverage

Shingles	$ 7.25
Labor	5.25
Nails	0.40
Starter strip	1.00
Total	$13.90

Figure 84 shows these costs of labor and materials graphically.

The average asphalt shingle roof that was inspected had four nails to a strip shingle. The most prominent type of asphalt shingle in use in Iowa is the square butt. The cost of a square butt asphalt shingle per square applied with five inch exposure and four nails is about $13.70. This same shingle with six nails instead of four would cost $14.45. Any manner of application on the preceding pages has been used but some are preferable to others. Different types of buildings on a farm could make better use of one style than some others. The pattern that is preferred is a manner of opinion for each person to determine according to his own judgment.

The house is the most prominent building on a farm. The type of application that would be preferred by the author for a house is number 8. This would give a square butt shingle with five inch exposure, six nails and cement. This type shingle is chosen for its good appearance and wind resistance. The next type that would be chosen is

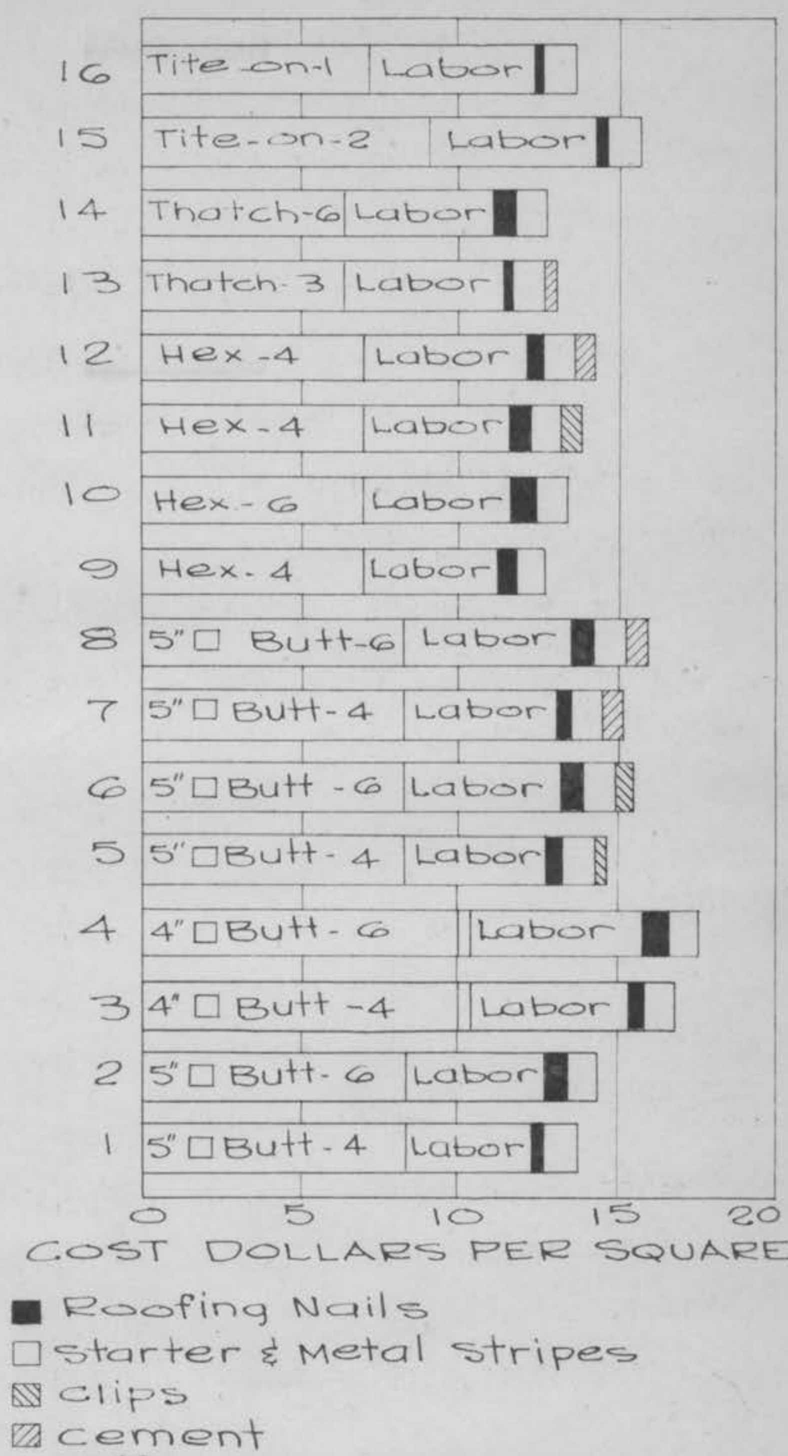


FIG. 84. COST ASPHALT SHINGLES

number 12. This hexagonal shingle is probably not as good looking as number 8 but more economical and as wind resistant. Number 13, thatch type, which is the most economical shingle that could be recommended for use on a house, gives average appearance and good wind resistance. Either the square butt shingle with six nails and clips or the hexagonal shingle with clips is as good as the square butt or hexagonal shingle with cement, except the author does not like the appearance of them on a house. Clips have a definite advantage over cement in one way--in that one can be sure when all tabs on a roof are fastened, whereas this is much harder to determine when the tabs are cemented. The tite-on shingle will also give good service and would come in this order of preference.

On all other buildings on the farm, if the appearance of the roof is not too important, the use of the following roofs would be chosen in the following order, as one will give as good service as the other if they are of the same material and are chosen for economy's sake: (1) Number 13, thatch type cemented, \$13.30; (2) Number 16, tite-on, single coverage, \$13.90; (3) Number 11, hexagonal, four nails and clips, \$13.95; (4) Number 12, hexagonal, four nails and cement, \$14.35; (5) Number 6, square butt, six nails and clips, \$15.55.

These values will vary from place to place and if cementing could be done cheaper than clipping or any other manner of getting roofs with numbers 5, 8, 11, 12, 13, 15 or 16 done cheaper than another, these types of roofs would be recommended for use on farm buildings.

Cementing or clipping an asphalt shingle tab is recommended on any pattern that can use a clip or cement. The additional cost for an average dwelling is about $18.00 and this small amount is more than worthwhile. Over the lifetime of the roof it will pay for the additional cost many times.

Shingles that have been cemented have been said to buckle during hot weather. A number of roofs have been examined that have been cemented and in no instance was this found true. The roofs varied in time that they had been cemented from 19 years to two weeks. Figures 81 and 82 show asphalt shingles that were cemented two years ago. The temperature on the roof was 135° F. and there was no evidence of any bulging effect, as the pictures show.

CONCLUSIONS

Good and Damaged Asphalt Shingles

1. Trees, a hill or other buildings were very helpful in protecting asphalt shingles from wind damage.

2. Protection of an asphalt shingle from the sun by the shade of trees was beneficial in prolonging the life of a shingle.

3. The southern exposure of a roof will wear out first due to the sun, if the asphalt shingle was not damaged first by wind or hail.

4. As shade from trees is not always possible, a material that might be developed that could seal the bitumen in a shingle and reflect the rays of the sun would be of great material help.

5. There was no area on a roof that was more susceptible to damage than any other area.

6. No one group of individuals can be blamed or given credit for poor or good application of roofs.

7. Houses had the highest percentage of losses of any of the farm buildings and, likewise, they had the highest percentage of asphalt shingle roofs.

8. There was no evidence of proof that a flat roof

such as gable, ganbrel, etc., was any more susceptible to damage than was a curved roof such as gothic or round.

9. The use of nails to fasten tabs down when they tend to blow up was found harmful and this manner of repair cannot be recommended or approved.

10. The use of a starter strip and a metal edge strip was found advantageous and their use is recommended.

11. The use of a 15 pound roofers felt was found to be neither beneficial nor harmful.

12. The best type of asphalt shingle to apply was not determined. The final decision of this must lay with the person applying the roof after the advantages and disadvantages are weighed.

13. The thatch type, three tab hexagonal, and the square butt shingles of the tab type shingles were found to be wind resistant in the order named by the use of the area exposed to the distance bent, with the thatch type the most wind resistant and the square butt the least wind resistant.

14. Asphalt shingles listed as "other", which includes such types as individual, thatch type, tee-lock, and tite-on, had a higher percentage of failures than the percentage in use.

15. The tite-on shingle has been found to have given good service on Iowa farm buildings.

16. The average age of failure of asphalt shingles was found to be 7.03 years in 1947-48 by the author, whereas

the average age of damage was found to be about eight years in the study of Esmay's (3) in 1946.

17. Good asphalt shingles were found to be 10 percent thicker than damaged asphalt shingles which makes the good shingle more rigid and longer lifed due to the availability of more bitumen.

18. Good asphalt shingles had 0.63 inch less exposure than the damaged asphalt shingles.

19. Damaged asphalt shingles had 0.79 inch more distance from the edge of exposure to the point of nailing than did the good shingles.

20. The average moment exerted on the damaged shingles was about 1.3 times as great as the moment on the good asphalt shingles due to more exposure and higher nailing.

21. A three ply coverage asphalt shingle roof could be damaged as readily as a one ply coverage if neither had their tabs fastened.

22. Nail heads should have at least 7/16" D heads or larger to avoid pulling out through an asphalt shingle.

23. Cementing the tabs down must be done with care if the tabs are expected to be firmly fastened.

24. Cementing the tabs down was found to give excellent warranty against wind damage.

25. Clips used to fasten the tabs have given excellent service and their use can be recommended to make an asphalt shingle wind proof.

26. Repair work should be carefully and properly done with new shingles replacing the old ones, proper nailing and cementing or clipping the entire roof area in order that failures are not repetitious as they were found on many roofs on Iowa farms in 1947-48.

27. Good asphalt shingles had about 70 percent more nails per square than did damaged shingles.

28. The right amount and proper location of nails were found to be very important.

29. The amount of about $3.00 per roof would have properly nailed the average damaged shingle and undoubtedly would have eliminated much of the damage found.

30. An old wood or asphalt shingle roof was a poor deck on which to apply new asphalt shingles as this type of deck made poor material in which to fasten the nail, to avoid wind damage and nearly always assured damage occurring when hit by hail.

31. A perfectly smooth deck was found to be the best deck to which an asphalt shingle could be applied.

32. Material that could fill the gaps below the butts of old wood shingles was found to be badly needed.

33. The average age of wood shingles when replaced by asphalt shingles was found to be about 28 years.

34. Self-sealing of asphalt shingles was found to be highly desirable.

35. Nails driven at any angle but 90° were found to

out asphalt shingles and cause failure.

36. The average force that was required to lift the average damaged asphalt shingle was found to be about 4 pounds per square foot.

37. The average force that was required to lift the average good asphalt shingle was found to be about 5.75 pounds per square foot.

38. By computation of velocity with the experimental and the straight line formula it was found that a wind velocity of about 27 m.p.h. could have lifted the average damaged asphalt shingle tab. It would have required a velocity of about 33 m.p.h. to lift the average good asphalt shingle.

39. Asphalt shingles absorb a good deal of heat from the sun. Temperatures on the shingle roof were found that exceeded air temperature by 67° F.

40. High temperatures caused the force required to lift the tab or to pull a nail head through the asphalt shingle to decrease.

41. Most damaged asphalt shingles failed due to the tabs breaking and coming off the roof.

42. Hail loss will occur on an asphalt shingle if the deck is not perfectly smooth.

43. Asphalt shingles that have a smooth deck under them will show no material damage if hit by hail but should be dressed with an asphalt coating.

44.Ten percent of the average roof area was found damaged.

45. Insurance agents and lumber dealers believed that failure was due to improper nailing and to the fact that the tabs were not fastened down.

46. Insurance agents and lumber dealers recommended the use of a thick asphalt shingle.

47. Lumber dealers believed that roofers felt was necessary and that starter strips were not; however, the author could not substantiate this.

48. The use of clips and cement was recommended by both lumber dealers and insurance agents.

49. The weather at time of application was believed by lumber dealers and insurance agents to affect the life of an asphalt shingle. This was found true and a still day with air temperature around 75° F. was found nearly ideal for application.

50. Less than 50 percent of the lumber dealers recommended the use of an interlocking shingle, while 90 percent of the insurance agents recommended it.

51. Asphalt shingles have been found to seal by about 60 percent of the lumber dealers and insurance agents. Self-sealing of about one percent of the roofs was also found by the author.

52. Asphalt shingles have the advantages of fire resistance and good appearance and have the disadvantages of

low life expectancy and wind damage.

53. Wood shingles have the advantages of average life and high wind resistance and have the disadvantages of fire hazard and high cost.

54. Asbestos cement shingles have all the advantages of any roof and the disadvantage of high cost.

55. Aluminum and steel have the advantages of fire proofness and low cost and the disadvantage of wind hazard and poor appearance.

56. A square butt asphalt shingle with a five inch exposure, six nails and cemented is recommended for use on a farmhouse roof.

57. Any pattern of asphalt shingle that is either interlocking or able to be clipped or cemented is recommended for use on the other farm buildings. The pattern chosen should then be dependent upon which could be applied the cheapest.

58. The pre-war two tab hexagonal shingle gave much better results in the laboratory than did either the post-war square butt or three tab hexagonal shingle.

59. Whether the material in the damaged asphalt shingles was to blame was not determined in this study. However, asphalt shingles were seen that were worn out in less than fifteen years. This cannot be considered as good service and the blame must be placed on the material in these few instances.

60. A force of about 16 pounds was required to pull a tab loose from the shingle below when the tab was cemented or clipped. This force would withstand a wind velocity of 100 m.p.h.

SUMMARY

1. Esmay (3) found that the probable chance of damage to asphalt shingles by wind and hail was 15.4 as great as was probable chance of damage to wood shingles in Iowa in 1946.

2. The total amount paid out by Iowa farm owners in 1946 was about $125,000.

3. The total amount paid out by the Iowa city dweller in 1947 was about $290,000.

4. The objective of this study was to find what caused failure in an asphalt shingle and what could be done to determine what a good asphalt shingle roof comprises.

5. Asphalt shingles have been in common use since 1911 and are gaining in popularity every year.

6. The best pattern and method of application of asphalt shingles have not been determined.

7. Laboratory work was done to determine the physical make up of asphalt shingles, the amount of pounds pull to pull a nail head through asphalt shingles at various temperatures, the pounds pull to lift the tab of asphalt shingles 4.25 inches at various temperatures and the number of bends, tabs of various pattern shingles could be bent through 90° at various temperatures.

8. Red cedar wood and asbestos cement shingles were broken at the edge of exposure to determine what wind velocity they could withstand.

9. Thirty-six good roofs were inspected in 34 counties in Iowa in 1947-48.

10. One hundred seventy-two damaged roofs in 69 counties were inspected in Iowa in 1947-48.

11. One hundred five lumber dealers and insurance agents were interviewed in 67 counties.

12. The resistance of tabs to wind pressure was found to be inadequate whenever roof temperatures reach 100° F., which temperature can be reached with air temperatures as low as 75° F.

13. Trees, a hill or other buildings were very helpful in protecting asphalt shingles from wind damage.

14. Protection of an asphalt shingle from the sun by the shade of trees was a great deal of help in prolonging the life of a shingle.

15. No one group of individuals can be blamed or given credit for poor or good application of roofs.

16. The use of a starter strip and a metal edge strip was found advantageous and their use is recommended.

17. The use of a 15 pound roofers felt was found to have no beneficial use and no harmful use.

18. The best type of asphalt shingle to apply was not

determined. The final decision on this must lay with the person applying the roof after the advantages and disadvantages are weighed.

19. The thatch type, three tab hexagonal and the square butt shingles of the tab type shingles were found to be wind resistant in the order named by the use of the area exposed to the distance bent with the thatch type as most wind resistant and the square butt the least wind resistant.

20. The tite-on shingle has been found to have given good service on Iowa farm buildings.

21. The average age of failure of asphalt shingles was found to be 7.03 years in 1947-48 by the author, whereas the average age of damage was found to be about eight years in the study of Esmay's (3) in 1946.

22. Good asphalt singles were found to be 10 percent thicker than damaged asphalt shingles which makes the good shingle more rigid and longer lifed due to the availability of more bitumen.

23. The average moment exerted on the damaged shingles was about 1.3 times as great as the moment on the good asphalt shingles due to more exposure and higher nailing.

24. A three ply coverage asphalt shingle roof could be damaged as readily as a one ply coverage if neither had their tabs fastened.

25. Nail heads should have at least 7/16" D heads or

larger to avoid pulling out through an asphalt shingle.

26. Cementing the tabs down was found to give excellent warranty against wind damage.

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